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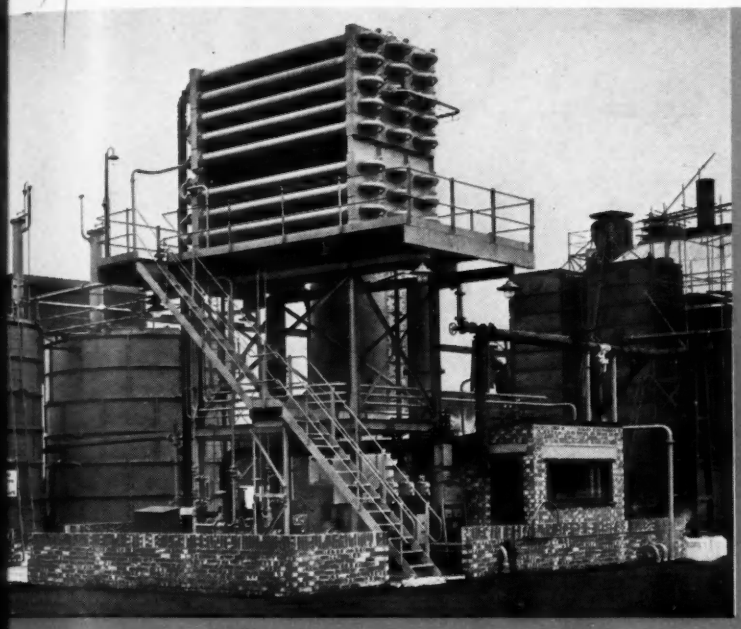
Gas Journal

VOL. 297. 111th YEAR LONDON, FEBRUARY 11, 1959 No. 4987 PRICE 1/6



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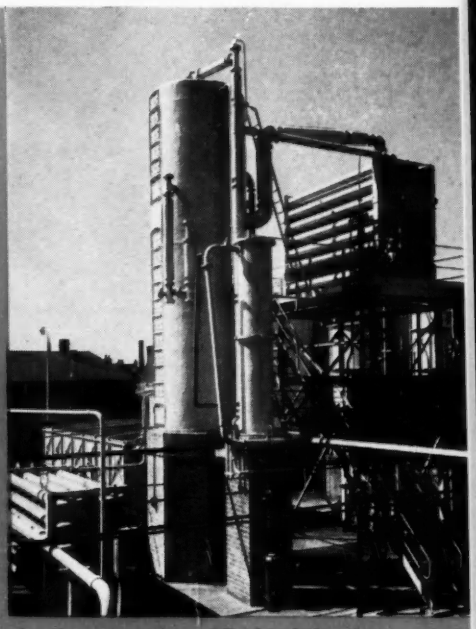

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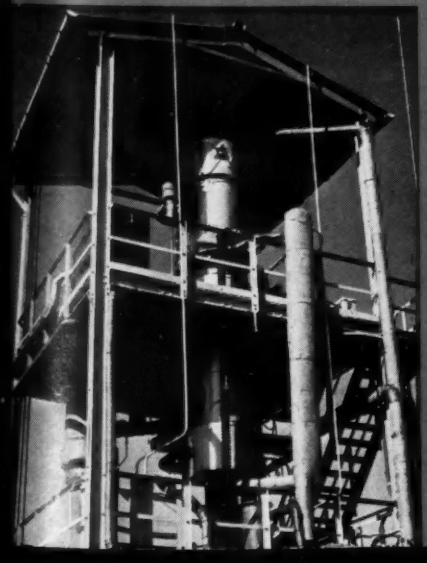

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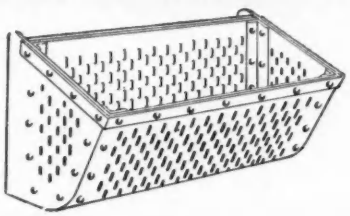

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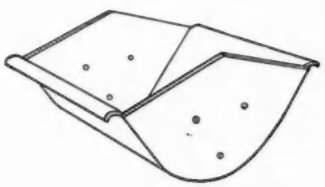

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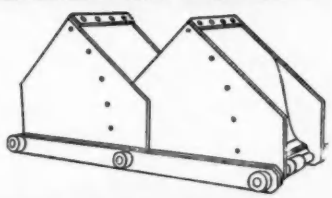

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Gas Journal

VOL. 297 NO. 4987 FEBRUARY 11, 1959

111TH YEAR

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Published by Walter King Limited,
11, Bolt Court, Fleet St., London, E.C.4

Telephone: FLEet Street 2236-7 Telegrams:- Gasking, Fleet.

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PUBLISHERS' NOTICE, See Page 249, February 11, 1959

Illustration by courtesy of H. E. Wingfield & Co.

something in common

They remind one of different worlds, the 1d. black postage stamp of 1840, and the modern T.G. meter. Yet, they *have* something in common—both are the products of true craftsmanship. First issued on 6th May, 1840, the 1d. black was printed by Perkins, Bacon & Co. from an engraving by Frederick Heath. The design was based on a watercolour by Henry Corbould from the City Medal engraved by William Wyon, and is presented as a fine example of the engraver's art. The T.G. meter epitomizes craftsmanship and the T.G. 'G' prepayment mechanism is accepted as the most modern precision movement on the market.

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Gas Journal

VOLUME 297. No. 4987 FEBRUARY 11, 1959. 111th YEAR

Fifty Vital Years in Retrospect

FIFTY years in the gas industry may not see the same degree of technical development as in, say, the oil or plastic industries, but nevertheless it is a sufficiently significant span for a great deal of importance to happen. Dr. Arthur Marsden, the former area chief scientist of the South Western Gas Board, celebrated his half century in gas by presenting to the South Western Section of the I.G.E. the long and extremely interesting paper which forms the bulk of the technical content of this issue. With characteristic thoroughness he examines this part of the industry's evolution from every possible aspect, lingering understandably long over purification and byproducts, and tripping lightly over distribution and utilisation. His comments on these technical developments our readers may read for themselves; our object in writing this note is to underline some of the conclusions which Dr. Marsden has reached in his distinguished career and his speculations concerning the future.

Consideration of the future necessitates giving some thought to nuclear energy, but in this Dr. Marsden sees no cause for alarm. He envisages the release of quantities of cheap, low grade coal for complete gasification, oil as a raw material for the chemical industry, and ultimately the employment of direct electrical heating and the production of hydrogen by electrolysis; and he makes particular mention of the effects of radiation on catalysts, quoting the effect found by Clarke and Gibson on an iron catalyst used in the Fischer-Tropsch synthesis where the rate of conversion was increased by about 50%.

Dr. Marsden also refers to modification of traditional carbonising plant, and the siting near sources of coal supply of large complete gasification plants having slagging producers and operating at pressure with steam and oxygen and to the tendency to erect plants near suitable refineries and ports, capable of gasifying or reforming a variety of feedstocks, from heavy oil to imported natural gas.

Referring to a national grid he points out that it is cheaper to transport gas at high pressures through mains than to distribute electricity through high voltage cables —and of course much cheaper than carrying coal by rail transport.

However, it was Dr. Marsden's comments on human relations which most attracted our attention. He notes that the ruthlessness of that ' rugged individualist,' the early gas engineer and manager, has been mollified by more recent events, and he recognises increasing signs of mutual understanding between those engaged in technical matters, such as production, research and process development, and those more immediately concerned with business and finance. This he interprets as ' business maturity ' and quotes as an example of this more enlightened outlook the importance being attached to work study. But it is significant that in his remarks on this increasing ' togetherness ' of the purely technical and the wholly financial Dr. Marsden makes no mention of those on the sales side of the industry who we are left to assume are as spiritually divided from their production colleagues as ever. Judging by his paper the author has not given a great deal of thought to the changing face of gas appliance marketing. This is understandable enough no doubt, but we would have said that one of the most significant changes taking place in the industry today is the gradual emergence of the commercial man as a power in the organisation. In the gas industry the overwhelming influence of the engineer continues to be felt, and in the circumstances it is unlikely that production and sales will appear as equal partners—for such they should be—for many years to come. Nevertheless, that particular evolution is taking place and we should have thought Dr. Marsden would have noted it.

One reference in the paper will no doubt strike an answering chord in many a breast. Education and training, health and safety, and human relations and welfare are excellent, admits Dr. Marsden, ' but in our enthusiasm to pursue this course we must also see that relative values are maintained and that human energy is not used unnecessarily. Various groups and associations now sponsor so many conferences, symposia, panel dis-

cussions and management courses that one begins to wonder how we shall go about trying to allocate our time . . . We must remember that the industrialist and the scientist may very easily get so absorbed in the tactical trees that they fail to see the strategical wood!'

Remarking that the industry tends to get into a rut on controversial topics and to go on arguing about the merits or demerits of issues long after they have ceased to be live ones, Dr. Marsden pleads for clear and incisive thinking, because so often the issue is simply one of deciding which method costs least for a given level of efficiency. And so say all of us.

Finally, pointing out that this is a great industry, of vital importance to the nation, and that it is much larger than the I.C.I., Unilever or any of the aircraft industries, Dr. Marsden says: 'If we strive to use our resources of capital and raw materials as effectively as possible we shall certainly obtain a fair proportion of the nation's estimated increase in energy requirements of 2% per annum over the next two or three decades'

The Mystery of Solid Fuel Supplies

PERIODS of cold weather in mid-winter are always testing times for the supply of solid fuel to the general public as well as to industry. If the householder is lucky enough to have good out-house accommodation, he will be able to store his fuel needs for the forthcoming winter by laying in supplies at the time of low demand the previous summer. Others, with less storage space, may be able to lay in an emergency stock of a ton or so for the coldest time of the year when demand on the coal merchant is at its greatest. The least fortunate will have to rely on the merchant delivering solid fuel bag by bag each week.

Often the calls on coke producers during extremely cold spells have been such as to make it impossible to satisfy the swarms of would-be customers wanting a ½ cwt. or the householder deciding to run his central heating temporarily on coke, since nothing else is available. Since and during the war, such a state of affairs only happens because of coal rationing. Today there is no coal rationing, but there are smokeless zones. The demand for smokeless fuel, however, appears to be making itself felt outside the smokeless zones.

Are the public then becoming clean air minded? This might well be so, especially since the reappearance of the smog in the south for a brief spell recently and its more prolonged stay in Scotland, will have brought back to many the memory of the dark days—literally and metaphorically—of the great smog of London in 1952. Whatever the reason may be, the demand for smokeless fuel has by all accounts increased and there have been complaints that there is not enough of it available.

The weekly stock returns of coke and other smokeless fuels to the Ministry of Power, would suggest that there may not be large quantities of premium fuels available for those outside smoke control areas, but supplies of coke should be adequate for all. Why then the complaints? It would seem that in certain areas the distributed stocks may not be adequate or that, if adequate, deliveries to individuals are not being treated with the importance and expedition they deserve. Once more the guilty party appears to be the coal and coke merchant. Is he loath to handle any fuel other than coal? Sometimes it would appear that he is, and the reason given for this discrimination is that, being of lower bulk density, coke takes up more room both to stock in his yard and to deliver in bags, and costs more in labour and transport to handle. Such an argument could not be applied to fuels such as phurnacite which have a considerably greater bulk density.

The fact that less coal is being consumed by the general public is confirmed in a speech by Mr. Peter Brewis, former chairman of the Society of Coal Merchants at a luncheon of the Coal Industry Society recently. He said that the slackening in demand for coal was profoundly disturbing and that there was apparently a strong switch away from solid fuel, much of which was due to propaganda by the electricity and gas industries. This statement gives, we think, a slightly different aspect to the solution of the problem of smokeless fuel. It might seem something of a paradox that the Clean Air Act, demanding as it does such a very high standard of smokelessness, should tolerate the burning of coal at all, except under perfect conditions of combustion.

In spite of the view taken by some that solid smokeless fuels contain about as much sulphur as coal and, therefore, little is gained by their use, it is the soot and tarry matter that does the damage by 'fixing' the sulphur on the buildings or by acting as nuclei for sulphurous rain drops. The fact that gas is being blamed for reducing the domestic coal demand, emphasises the success of the area boards' efforts to sell gas space heating appliances, which can compete in running costs with the use of solid fuel. This tribute is all the more welcome when it is universally accepted that the solid fuel therm is still the cheapest.

The increase in gas sales, however, does not necessarily reduce coke stocks or deliver coke to areas outside the limits of the gas supply networks, where smokeless fuels may be urgently needed. It does, however, point towards a change in the housewife's attitude towards the traditional open fire. The new generation want a standard of house warmth greater than what their parents could have possibly hoped for, but they do not want the trouble and dirt of the daily cleaning and relaying of fires. Modern gas ignited grates, the gas convector fire, or the gas fired central heating boiler are clearly the solution.

In fact, on several occasions we have attempted to make the point that until the right type of smokeless fuel, either solid or gaseous, is made available at a reasonable price to be consumed in a scientifically designed and well constructed appliance, no one will willingly change from the cheerful, traditional coal burning open fire. If the housewife can be convinced of the advantages of the new fuels, she will quickly make the change. Hire purchase should be able to provide the necessary finance.

Personal Notes

MR. R. W. P. HOLT, Director of Widnes Foundry & Engineering Co., Ltd., has retired. Mr. Holt has been a director of the Company since 1925, when it traded under the name of Widnes Foundry (1925) Ltd. He continued in that capacity when the Company was taken over by Thos. W. Ward Ltd., of Sheffield, in 1936, and the name was changed to Widnes Foundry & Engineering Co., Ltd. Mr. Holt is well known throughout the country and in Europe among chemical engineers and the chemical industry.

ALDERMAN JOHN HENRY LEWIS, O.B.E., who is Chairman of the West Midlands Gas Consultative Council and a part-time member of the West Midlands Gas Board, is to be the next Lord Mayor of Birmingham.

MR. F. DONACHY of Peebles has been appointed part-time member of the Scottish Gas Board from May 1.

MR. M. HAMSHAW has been appointed Managing Director of Chemical Engineering Wiltons Ltd. (subsidiary of Simon-Carves Ltd.).

Obituary

MR. J. G. O. DRAKE, General Manager of the North Western Gas Board's Liverpool Group, has died aged 63. Mr. Drake joined the staff of the Liverpool Gas Company in 1913 and thereafter spent the whole of his business life in the service of this company and later the North Western Gas Board. After considerable service in France during the first world war he returned to civil life and the Liverpool Gas Company in 1919. From that time he acted in the capacity of deputy accountant and later successively held the positions of chief accountant and treasurer, before being appointed sales manager and deputy secretary. In 1950 he was appointed general manager of the North Western Gas Board's Fylde Group of undertakings. On the appointment of Mr. C. H. Leach, general manager of the Board's Liverpool Group, to the chairmanship of the Southern Gas Board, Mr. Drake returned to Liverpool as his successor in January, 1956. Mr. Drake claimed that his education began when he left school. He gained his first professional qualifications by studying five nights a week for five years at night-school. Though this impaired his health, he never permitted ill-health to interfere either with his work or his enjoyment of living. Mr. Drake was an Associate of the Chartered Institute of Secretaries and a Fellow of the Association of Certified and Corporate Accountants.

Anniversary dinner

Donald Macpherson & Co. Ltd. recently celebrated the 21st anniversary of their annual dinner and dance at the Princess Ballroom, Manchester. The Chairman of the company, Mr. R. P. Chester, C.B.E., was unable to be present, but was represented by his son, Mr. Rex Chester, a Director. Long service awards were presented by the deputy Managing Director, Mr. W. N. Gilbert Harris.

Correspondence

The danger of water and vibration

DEAR SIR,

Broken and leaking gas mains may be caused by long periods of frost and by earth subsidence. (*See Editorial Comment, last week.*)

A leaky or broken water main may cause subsidence and be a danger to itself and also to a nearby gas main. This I know from experience.

Vibration caused by present-day heavy traffic is a danger to all underground services.

Yours faithfully,
'OLD HAND.'

Wimbledon, S.W.20.
February 5, 1959.

Board Chairman sees MPs today

THE group of Labour MPs for Birmingham constituencies who made representations to the Minister of Power about the large number of gassing accidents that have occurred recently in Birmingham, will meet Mr. G. le B. Diamond, Chairman of the West Midlands Gas Board at the House of Commons today.

After discussing the accidents, Mr. Diamond will accompany the MPs to Watson House where he will show them the development work which is being conducted on safety devices for gas apparatus.

Diary

February 12.—LONDON AND SOUTHERN JUNIORS.—Visit to the Acton Bolt Co., Ltd. 2.15 p.m.

February 18.—SCOTTISH G.C.C.: 26, Drumsheugh Gardens, Edinburgh. Council Meeting at 11.30 a.m.

February 18.—COMBUSTION ENGINEERING ASSOCIATION, SCOTTISH SECTION: North British Hotel, Edinburgh. Papers on 'The Insulation of Industrial Buildings,' by J. Lawrie, of Fibreglass, Ltd., and 'Case Histories of Fuel Savings,' by H. H. Grattidge. 10.30 a.m.

February 19.—MANCHESTER JUNIORS: Magnesium Elektron, Ltd., Clifton Junction, Manchester. Tour of works followed by address on 'Production Engineering and Works Study,' by representatives of Messrs. Urwick Orr & Partners, Business Management Consultants. 2.15 p.m.—paper at approximately 5.30 p.m.

February 21. — SCOTTISH WESTERN JUNIORS: Dumbarton. Conducted tour of gasworks; lunch at Dumbuck Hotel and a paper on 'Management and Plant,' by A. M. Jackson. 10.30 a.m.

February 24. — INSTITUTE OF FUEL, SCOTTISH SECTION: Royal College of Science and Technology, Glasgow. 'Present Trends in Research on Coking Properties of Coals,' by Helen McKellar. 7 p.m.

February 25. — INSTITUTE OF FUEL, LONDON SECTION: Institution of Civil Engineers, Great George Street, London, S.W.1. 'Investigations in Germany Concerning Atmospheric Pollution,' by Dr.-Ing. H. Lent. 5.30 p.m.

February 25. — WALES AND MON. JUNIORS, SOUTH WALES SECTION: Newport. Paper by Mr. H. Breeze, Pipe-line Construction Engineer, Wales Gas Board.

February 25. — WALES AND MON. JUNIORS, NORTH WALES SECTION: Connah's Quay. Paper on 'Space Heating.'

N. Ireland

LISBURN U.D.C. TO SPEND £120,000 ON NEW VERTICAL RETORTS

MINUTES of the Gas Committee adopted by Lisburn Urban Council contain a recommendation of the Gas Manager, Mr. G. A. McNiece, to instal new vertical retorts in the gasworks to replace the horizontal retorts at an estimated cost of about £120,000.

Mr. McNiece told the committee that a plant with a daily capacity of 500,000 cu.ft. was required. The new plant recommended would solve all problems regarding pressure.

The local government auditor's report on the accounts of the gas undertaking for the year ended March 31, 1958, stated that the trading account showed a loss of £3,931, notwithstanding an increase of 1s. 6d. per 1,000 cu.ft. of gas, effective from July 1, 1957.

The loss was explained by a decrease of 4,759,200 cu.ft. in consumption, having a monetary value of £2,788 and a drop of £2,121 in the sale of residuals.

Boiler flues—a correction

In our report of the discussion on the paper by Bennett, Brady and Dance last week we quoted Mr. W. L. Howe (on p. 186) as recommending 'shot-blasted steel pipe' as a suitable material for boiler flues. This should have read 'salt-glazed sewer pipe.' We apologise for the error.

Officials at the General Meeting of the South Western Section of the I.G.E. Left to right: Mr. J. C. Hogg, Chairman of the London and Southern Section, Mr. P. P. MacDiarmid, Chairman of Willey & Co., Ltd., Mr. E. M. Edwards, President of the Institution, Mr. G. F. Oliver, Chairman of the South Western Section: Mr. C. H. Chester, Chairman of the South Western Gas Board, Dr. A. Marsden, former Area Scientist, South Western Gas Board, and Mr. F. C. Gay, Hon. Secretary and Treasurer, South Western Section.

I.G.E. President at South Western Section meeting

IN spite of very difficult weather conditions of snow, ice and fog, there was an attendance of 64 at a general meeting of the South Western Section of the Institution of Gas Engineers held at Exeter.

Before the meeting, members visited the works of Willey & Co., Ltd., in Exeter, by kind permission of the Chairman, Mr. P. P. MacDiarmid.

Lunch was taken at the Rougemont Hotel, Exeter, following which the Chairman of the Section, Mr. G. F. Oliver, M.B.E., formally welcomed the President of the Institution, Mr. E. M. Edwards, together with Mr. J. C. Hogg, Chairman of the London and Southern Section, and expressed the thanks of the Section to Mr. MacDiarmid and his co-directors for the arrangements made for the visit in the morning.

In reply, the President expressed his pleasure at being able to be with the Section and paid tribute to the way in which it was served at Institution level by the Ordinary and District Members of Council. Mr. Edwards reviewed trends in the gas industry and the changes which were constantly taking place as a result of competition and demand. The space heating load presented a wonderful opportunity for development, particularly for the complete displacement of the solid fuel fire.

The general meeting in the afternoon was presided over by Mr. G. F. Oliver, M.B.E., Chairman of the Section, who welcomed the Chairman of the South Western Gas Board, Mr. C. H. Chester, C.B.E., who was able to join the members at this stage.

Dr. A. Marsden, M.B.E. (former Area Scientist to the South Western Gas Board) presented his paper—'Reflections on 50 Years in the Gas Industry.' (See p. 231).

Industrial safety equipment makers form association

THE problem of safety for workers in industry has been accentuated by the new techniques, processes and materials now coming into general use. Manufacturers of industrial personal safety equipment are in process of forming a special association, the objects of which include the improvement of standards in design and construction of such equipment and the promotion of education on its uses.

It is believed that the programme envisaged by the new association will have a considerable effect upon accident reduction in British industry.

A meeting is to be held on February 17, at 2.30 p.m., at the headquarters of the National Union of Manufacturers, 6, Holborn Viaduct, E.C.1, to which all those concerned with the manufacture of industrial personal safety equipment are invited. At this meeting, a draft constitution will be submitted which, on adoption, will enable the association to be formed officially and to commence operations.

Board holds lifting and handling course

A six-day course on manual lifting and handling was held recently at Saltisford, Warwick., by the West Midlands Gas Board.

Speakers at the course were Mr. H. Moys, Chief Engineer, Mr. J. B. Cronin, area Safety Officer, and Mr. George Hickling of the Central Council of Physical Recreation.

The course included teaching demonstrations, conditioning exercises, films, and the handling of industrial equipment.

STEEL & CO. MAKE BID FOR R. H. NEAL

AN offer to buy the whole of the ordinary stock of R. H. Neal & Co., Ltd., makers of the well known Neal mobile crane, has been made by Steel & Co., Ltd., of Sunderland.

The company also reports the purchase of the crane business of F. Taylor & Sons (Manchester), Ltd., makers of the Taylor Jumbo mobile crane.

Three largest

As Steel & Co., Ltd., already owns the whole share capital of Steels Engineering Products, Ltd., manufacturers of Coles mobile cranes, it will control three of the largest British manufacturers of mobile and rail cranes.

The object of this amalgamation is to combat the aggressive bid of Continental crane manufacturers for world markets. In anticipation of the European Common Market manufacturers in Germany and France have been closing their ranks and rationalising their production which puts them in a favourable position to compete with the larger but less integrated British industry.

The three manufacturing companies will continue to produce their individual and distinctive models in their own factories and will trade as entirely separate entities competitively in Great Britain. In foreign markets, however, the resources of the three factories will be pooled for maximum advantage in securing the greatest possible share of available world business.

Rationalised

Considerable economies in design and manufacture are eventually anticipated as the products of the three companies are gradually rationalised.

From a paper to the Midland Junior Gas Association, November 25, 1958.

The Genealogy of Remote Control

By A. L. HANCOCK, B.Sc.(Eng.),
DIRECTOR, WALKER, CROSSWELLER & CO., LTD.

THE term 'remote control' as used in this paper may be defined as the operation and supervision of some engineering plant by one or more persons who are at a distance from the plant. The essence of remote control is that it is not necessary to have a man at the plant itself. It is of course possible to carry the development a stage further and to have remote automatic control, in which human intervention is not needed; in this case events occurring at one place control a plant at another. It is sufficient however to mention this possibility without going into further detail at present. In order to control a plant at a distance, two things are necessary; information as to what is happening at the plant must be conveyed to the distant operator, and orders given by the operator must be conveyed to the plant, where they are obeyed automatically. The difference between a message which is received and interpreted by a human operator, and a message which automatically performs some task is too small to require much comment. Any message sent by electrical means and received by an operator must produce an effect which he can detect by one of his five senses, usually the eye or ear. If there is no operator, and the signal has to perform some task itself, there is no difficulty. A very important difference to bear in mind, however, is that at the plant, messages are sent automatically, and received messages have an automatic effect, whereas at the other end of the line, the operator receives indications by eye or ear, and sends his orders by hand. This consideration does have some effect upon the techniques employed.

Communication theory. In recent years an entirely new branch of science has been developed, known as the theory of communication. The writer is not competent to go far with this subject nor is it necessary, but one of the first principles will help our present purpose. The smallest amount of information which can be conveyed from one person to another is known as a 'bit.' A message giving one 'bit' of information merely distinguishes between two possible things—yes or no, on or off, safety or danger. At one time in our history, the beacon on the hilltop would mean 'Napoleon has landed,' and if the beacon was not lit the message would be 'Napoleon has not landed.' The complexity of a message can therefore be expressed as the number of bits of information it contains.

Practical Importance

Applying this theory to an alarm signal, one bit of information may be sufficient. On the other hand, applying it to the reading of an instrument such as a pressure gauge, we may need a good deal more. One bit of information might indicate that the pointer was either in the upper half or the lower half of the scale but this information is too incomplete to be of much use. Assuming the pointer to be in the upper half, a second bit of information might specify the quarter of the scale within which the reading lies. If a third bit were given, it might specify which eighth, and so on. Putting this in another way, with one bit of information we can signal only two possible readings; with two bits, four readings; with three bits, eight readings, and so on, doubling each time. With seven bits of information, there are 128 possible readings, and this would probably be considered adequate for the purpose. It will be appreciated that the apparatus needed to send seven bits of information may be very different from that which is sufficient for one bit only, and since both the examples given—the alarm signal and the pressure reading—are commonly required in the gas industry, both examples are of great practical importance.

Five Methods

We must now consider the various ways in which electricity can be made to convey information. Apart from certain abstruse possibilities which need not concern us, there are five methods available and each will be considered in turn.

1. Varying voltage, current or resistance. This method is extremely simple in principle, consisting only of a variable resistance—or some equivalent device—at the sending end, and a measuring instrument—ammeter or voltmeter, etc.—at the receiving end. This method is very widely used and very satisfactory but it suffers from certain disadvantages which strictly limit its application. The chief of these is the need to keep the resistance of the connecting wires constant. Over short distances this is not difficult, but when the distance is measured in miles variations are inevitable. It is perfectly possible to have apparatus which will automatically test the resistance of the line immediately before a reading is signalled, and make due allowance for any variations, but this is an undesirable complication. This method accordingly finds little application in remote control as ordinarily understood, although for local readings it is widely used.

2. Varying frequency. There is no difficulty in generating an alternating current and altering its frequency, either by a measuring instrument or by any other device, so that different frequencies have different meanings. The telephone is, of course, an application of this principle. The only real objection to this method as far as our purpose is concerned, is that it is probably not the simplest and cheapest, although under certain circumstances it is the best yet developed. It is used, for example, in sending signals from meteorological

balloons, sputniks and moon rockets but it does not appear to have been applied to any extent within the gas industry.

3. Varying phase angle. This method must be mentioned because it is excellent for short distances: there are also closely allied methods based on the measurement of an electrical ratio, but three wires are usually needed. Since the communicating line usually available in the gas industry is a telephone line, which has only two wires, and because of other limitations, this method need not be discussed in detail.

4. Varying duration of current. By varying the time within which the current is allowed to flow, the signal can be varied and it is easy to send seven or eight bits of information in this way. The signal is of course repeated as often as necessary, either continually or when circumstances require it. This method will be discussed later in some detail.

5. Coded impulses. This was the earliest method used in telegraphy and its use now is much more widespread. In the Morse code, impulses of two lengths are used—dots and dashes—so that the Morse code is mainly a combination of types 4 and 5 although the duration of each impulse is not critical. In the dialling system used in automatic telephone exchanges, groups of impulses are arranged to represent the number to be dialled, and the method is widely used in electronic computers, so that it is considered by many people to be the most important method of the future. Further reference is made to this method later on.

Multi-channel Working

Before we can consider fully the relative merits of these different methods of signalling we must introduce another requirement which is almost universal in remote control where the distance exceeds a few hundred yards. Generally it is desirable to use only one line, *i.e.*, one pair of wires or one radio circuit. If several independent signals are to be sent over a single line in this way, there must be some means of distinguishing them at the receiving end. This system is known as multi-channel or multiplex working and it is of great practical importance. It was first introduced into telegraphy, and is now common in telephony. There is a very great variety of tricks and dodges which inventors have proposed for multi-channel working, but for practical purposes we need only distinguish between two methods, both of which will serve the purpose admirably. Both are in common use.

(*a*) The various signals may be intrinsically different, so that the receiving apparatus can distinguish between them, and respond to each signal independently. In practice, the difference between signals which is suitable for this purpose is a difference in frequency.

(*b*) The signals may be sent at different times, that is to say, the various signals are sent in succession, the whole series being repeated, either continually or as often as necessary.

These two methods are known as 'frequency division multiplexing' and 'time division multiplexing,' respectively.

We are now in a position to examine the different combinations of method of signalling and method of multiplexing, leaving out, however, those which do not appear at present to be of much practical importance in the particular field with which we are concerned. The possible combinations are shown in Table 1. It will be seen that there are eight methods for consideration.

TABLE 1
Methods of multiplex signalling

Type of signal	Method of multiplexing	
	a. Frequency division. (A different musical note for each channel)	b. Time division. (The various channels follow each other in sequence)
1. Variation of voltage, current or resistance	1a. The notes vary in loudness	1b. The signal for each channel varies in intensity
2. Variation of frequency (cycles per second)	2a. The notes vary slightly in pitch	2b. The notes vary in pitch
3. Variation of phase angle or ratio	3a. This type has not been developed for multiplex working	3b. Not developed but there is a great similarity to 1b
4. Variation in duration of current	4a. The notes vary in duration	4b. The signals vary in duration
5. Coded impulses	5a. The number, length and timing of the notes varies	5b. The number, length and timing of the signals varies

Method 1a, signalling by varying the voltage, current or resistance, with frequency multiplexing. It is difficult, at the receiving end, to separate a current at one frequency from a current at another, without impairing the intensities of these two currents. So far as the writer is aware, this method has never been developed for remote control. We can regard this method as using several musical notes, each varying in loudness and the only difficulty lies in controlling and measuring the loudness with sufficient accuracy.

Method 1b on the other hand, is quite commonly used, the principle being that a number of sources of voltages are connected to the line in turn by a selector switch. The various readings are received in sequence, and provided some means is available to indicate at the receiving end when each sequence starts, there is no difficulty in making a satisfactory scheme. In practice, however, this method has been used in conjunction with 5b, particularly for the examination of a number of temperatures which are of little interest provided they do not vary from the normal figure. Since each signal takes a certain amount of time to send, and quite a large number may have to be sent in sequence, each signal is sent at relatively long intervals of time, which may be a disadvantage.

Carrier Frequency

Method 2a. The signal is given by variation of frequency. This is the method used in telephony and radio. In the latter, one channel is separated from another by its different frequencies. Although the experience of tuning a radio set to any selected station is a very common one, the use of frequency in two different ways can be confusing and a short explanation may therefore be desirable. In this method each channel has its own frequency, which is known as a carrier frequency. The values adopted are necessarily higher than the values of the frequency which makes up the signal. In the case of radio, for example, the carrier frequency of one station may be one million cycles per second and no other station uses that figure. The signal frequency, which is superimposed upon the carrier frequency is very

much lower, seldom exceeding twenty thousand cycles per second. Precisely the same system is applied to multiplex telephony, and a call between Birmingham and Edinburgh would almost certainly use this method, but the frequencies are not so high. The highest frequency needed to convey speech clearly is about 3,500 cycles per second, and the lowest carrier frequencies which it is practicable to use for the various channels are approximately 8,000, 12,000, 16,000, etc., cycles per second. The difficulty with this arrangement is that the higher carrier frequencies are really much higher than the ordinary telephone line will convey, and it is therefore necessary to use a very special type of line provided with repeating apparatus at frequent intervals. Such a line would not normally be available for remote control in the gas industry.

Method 2b. Frequency signalling with time division. As far as the writer is aware, this has no particular advantages and is therefore not in common use. If such a system were used, a telephone connected to the line would pick up a tune, consisting of a succession of musical notes; each note would vary in pitch from time to time, in consequence of changes in the signal which each note conveys. Since the notes follow each other, each one could be allowed to vary over the whole audible range. This would not be the case of Method 2a, in which all the notes are sounding together, and therefore each one has a very limited range of variation.

Method 4. Here the duration of the signal varies in accordance with the message to be conveyed. It is a practical method and has important advantages in that it is particularly easy for a measuring instrument to generate a signal of this type in a satisfactory way. While time division is quite practical, it would suffer from the delay mentioned in connection with Type 1b, and therefore frequency division is to be preferred. This is the combination which has been selected for Arkon remote reading instruments, and further details will be given later.

Method 5. Here coded impulses are used and the method is of extremely wide application. Anyone who has listened to wireless telegraphy has no doubt heard several messages in Morse being transmitted simultaneously, but as each signal has its own musical note it is not difficult to distinguish one from another; the ear is quite selective in this respect.

Method 5b. Coded impulses with time division. We have many examples, notably the dialling on an automatic telephone. In general, Method 5 is excellent for occasional signals, but is perhaps less suitable for the continuous sending of an instrument reading, because it involves more complication, and more wear and tear on the mechanism, than is really necessary to achieve the result. For this reason, the Arkon system uses 5b for alarm signals and operational signals, but not for continuous reading, where Method 4a is used as already explained.

Innumerable Variations

It will be appreciated that variations of these methods, and combinations of them are innumerable and almost every day fresh ideas are introduced. However it would be out of place in a paper of this description to go too deeply into the theoretical possibilities, because we are really concerned with the service which can be given to the gas industry at the present time. We have, however, mentioned the chief methods available, and some attempt has been made to put them in their proper perspective.

The requirements of the gas industry. While it is not desired to suggest that the gas industry is alone in its need for remote control, there are certain differences between the various applications of remote control which have a considerable influence on the equipment needed. We must therefore consider a typical scheme, which has developed naturally as a result of the integration of the industry, the closing down of smaller works, and their conversion into unattended holder and governor stations. Despite many variations of detail, the general picture is nearly always the same; from a manned control room it is desired to supervise one or more unattended stations, and in addition to watching that all goes well, it is necessary from time to time to adjust governor settings, open or close valves, and perform similar operations, perhaps at a distance of 20 miles or more. The requirements of the operator in the control room can be classified under three headings.

1. Continuous indications of pressures, holder stocks, perhaps rates of flow and possibly other measurements. In certain cases a continuous chart record in the control room may be desirable but generally dial-and-pointer indication is sufficient.

2. Alarm signals, sent automatically when necessary, from the holder or governor stations, showing abnormalities such as low holder or low pressure, or perhaps excessive rate of flow, failure of a booster or any other condition important to the actual scheme.

3. Operational signals, by which the operator in the control room can open or close a valve, adjust a governor, start or stop a booster, etc., at any or all of the holder or governor stations.

Matter of Degree

It has already been explained that continuous measurement requires about seven ' bits ' of information, whereas an alarm-signal is usually covered by one bit only. The operational signals occupy an intermediate position; a ' start ' or ' stop ' signal needs only one bit, but the adjustment of a governor is a matter of degree or amount, and several bits will be necessary, to distinguish between a small and a large adjustment, as well as between ' increase ' and ' decrease.'

In designing the Arkon remote control equipment, the first decision was that the alarm and operational signals should be considered together, with the continuous indication of measurements as a separate consideration: One channel is, therefore, devoted to all the signals, and a separate channel to each continuous measurement. The channels are separated by frequency division. The use of time division appeared to require rather more complication and expense, and there was a risk of undue slowness of indication, whereas frequency division is a simple and reliable method. When more than two stations are to be interconnected, time division involves certain difficulties, because some form of synchronisation between stations is essential, and with a large number of channels this becomes rather difficult. It will

be appreciated that, while practically anything is possible with modern electronics, initial cost and maintenance must be considered.

It is highly desirable to have an evenly divided scale on the indicator, because it is so much easier to read without error. It so happens that with variable duration signalling (type 4, above) it is extremely simple to obtain any desired scale shape. A rate-of-flow meter usually has a square root scale, but this can be converted in the simplest possible way if a variable duration transmitter is selected. Another advantage of this device is that it does not impose any perceptible load on the measuring instrument, which can therefore operate with unimpaired accuracy. It was for these reasons that type 4a was examined and it was found possible not only to transmit a reading by extremely simple means, but to display it at the receiving end on either an indicator or a chart recorder in a very satisfactory manner.

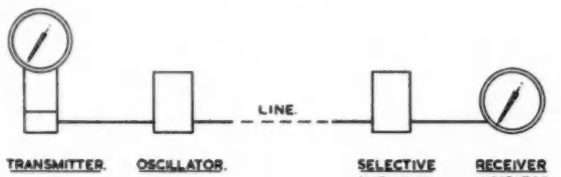

Fig. 1. The equipment necessary for one measurement channel.

The equipment necessary for each channel (see Fig. 1) is as follows.

1. A transmitter, associated with the measuring instrument, and switching on a signal duration of which depends on the reading.

2. An oscillator which produces a fixed frequency, suitable for transmission along a telephone line, and switches this signal on and off in response to the working of the transmitter.

3. A selective amplifier, which is connected to the receiving end of the telephone line. This responds only to the one frequency to which it is tuned, and ignores other frequencies or direct current. It provides an electrical output only while the incoming signal is 'on.'

4. A receiving instrument, which is a simple mechanism operated by an electro magnet, which positions a pen or pointer, in accordance with the duration of the impulses received. This unit displays the received reading to the control room operator.

Utmost Flexibility

The above equipment forms one complete 'channel' which operates independently of the other channels on the same line. A transmitting instrument and oscillator can be connected to the line at any point, giving the utmost flexibility when one line connects a number of stations. There are many cases (which do not properly come under the heading of remote control) in which a separate line can be provided for each instrument. This is commonly the case when the transmitter and receiver are both in the same works. It is then possible to dispense altogether with the audio-frequency equipment, *i.e.*, oscillator and amplifier, and use merely a simple electronic relay. Because this is less expensive, the cost of providing separate lines is justified if the distance is short, say under half a mile.

The purpose of the signalling system is to provide both operational orders and alarm signals. The term 'alarm signals' is perhaps too narrow, because it is often desirable to have a signal showing some condition which may be quite normal, for example, whether a booster is running or has stopped. The principle used is not easy to classify. Frequency division separates the signal channel from those of the remote reading instruments; direct current is used for the signals, and this is the lowest possible frequency, *viz.*, zero cycles per second. The use of DC enables the signals to be battery operated and therefore independent of the public electrical supply. In the signal channel there is the further feature of time division, since various signals follow in sequence: and further, a signal may consist of several coded impulses. Finally, one of the impulses of a signal is of variable duration. The apparent complexity lies in the endeavour to classify the system according to the rules, rather than in the equipment itself which is of very simple construction, as the following description will show.

Each station is provided with a rotary selector switch or 'transceiver' with a contact arm moving over 18 studs. The switch is driven at a fixed speed by a governed electric motor, but it does not run continuously; it is started and stopped when necessary, and to assist prompt starting and stopping, the drive from the motor is through a friction clutch operated by an electromagnet. The several switches are arranged to keep in synchronism with the aid of signals transmitted along the line between stations. For example, all switches normally remain at rest on control stud No. 1, see Fig. 2. A signal applied to the line from any station will start all switches moving. Similarly, at two or more points (for example on studs Nos. 3 and 10) any switch which is ahead of the others will pause and wait for them all to catch up. Thus any slight imperfection of synchronisation is corrected before it can do

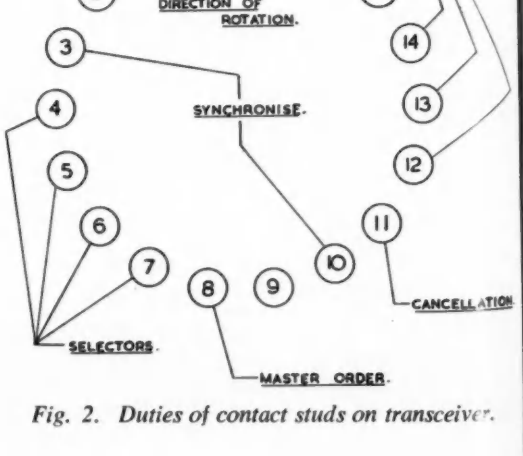

Fig. 2. Duties of contact studs on transceiver.

any harm. The provision of these synchronised switches opens up very considerable possibilities, for if one switch is arranged to send an impulse along the line while it is on, say, stud No. 7, then all the other switches will receive impulses while they are also on stud No. 7. It is only a matter of suitable electrical connections to make these impulses perform any desired task: and impulses sent on any other stud are quite independent. Apart from the studs used in starting and synchronising the switches, there are at least a dozen available for different signals, and these are utilised in the following way.

Assuming that there are not more than about a dozen operational signals—all of which are of course sent from the control room—the first 4 available studs will be used to send up to 4 impulses, making up a signal which identifies the particular operation to be performed. For example, impulses on studs Nos. 4, 5 and 7 might indicate one operational order; impulses on studs 4 and 5 would give a different order, and so on. Using four studs to send four bits of information, 16 combinations are possible, though not all would necessarily be used. The impulses are used to preset relays at the receiving station, making ready for the actual order itself; in other words, the impulses set up on an electrical circuit at the particular receiving station concerned. The next following stud is used to send the actual order which completes the circuit at the receiving station and performs the desired opration. A special feature of this stud is that while it is in use, the switches are stopped, so that the impulse which gives the final order can be made to last just as long as the operator thinks fit. As soon as the operator ends the impulse, the switches all resume their movement and eventually come to rest in their standing positions.

Amount or Quantity

The reason for this arrangement is that some operational orders have to include an indication of amount or quantity. If, for example, a governor is to be adjusted, then while the impulse lasts the adjustment is slowly being made. This makes it possible for the operator to adjust the governor setting to any desired extent. Again, if the purpose of the signal is to make a telephone call on the line, the call may last as long as desired. On the other hand, if the order is to stop a booster, a very short impulse is adequate, and the operator need not keep the order switched on any longer than he needs to observe that it has been sent, which is shown by the lighting of a pilot lamp. There is a further reason for separating the 'selection' impulses from the 'order' impulses. It is desirable that no fault which is at all likely to occur could possibly send a false order. The particular combination of impulses adopted is such that an accidental signal could hardly imitate it.

Fig. 2 shows the allocation of duties to the 18 contact studs, assuming the conditions specified above. The starting and synchronising functions have already been mentioned and the selector and master order studs are as described above. The next in sequence is the 'cancellation' stud, which serves two purposes; one will be described later, but the other purpose is to wipe out the selection of an operational order, by restoring the selection relays to normal, in readiness for the next signal. To do this the 'cancellation' stud must of course follow the 'master order' stud. A point to observe is that the cancellation stud is not used to send signals from one station to another; it gives a purely local signal which is effective at every rotation of the switches. We now come to the 'alarm' signals which may number, say, six. Since any of these may be 'on' independently of the others, the signalling of all six, in a single rotation of the switches, requires six 'bits' of information, and accordingly six studs are used, one for each alarm. If the number of alarm signals exceeded the number of studs available the electrical arrangements would have to be elaborated, but this is very seldom the case. Thus, in the example, each stud signals its own particular alarm, at each rotation of the transceivers.

Failure to Safety

There is a principle which has been adopted in railway signalling for many years; it is known as 'failure to safety' and requires that any fault should put a signal to the safer position, which is the one that stops the train. It is clearly desirable that we should follow the same principle; accordingly it is arranged that each stud sends an impulse if all is well, and the receipt of this impulse puts the alarm bell out of action. We can now explain the other purpose of the 'cancellation' stud. At the control room it puts all the alarms into operation immediately before the 'all's well' signals are due to be received. If one or more of them is not received, the appropriate alarm is left in action. This method tests the alarms automatically and ensures that no fault can go undetected. The alarm signal is displayed in the form of a red lamp and an audible signal, such as a bell. For each alarm an 'acknowledgment' switch is provided to put the bell out of action, because a fault condition in the plant (such as high holder) cannot always be corrected at once and the continuous ringing of a bell is disturbing to the operator. However, the correction of the fault, while it extinguishes the warning lamp, sounds the bell again, forcing the operator to re-set the acknowledgment switch in readiness for any repetition of the fault. If, while the bell is silenced, a different fault occurs, the bell will ring again until the corresponding acknowledgment switch is operated. It need hardly be mentioned that the sending of an alarm signal is quite automatic, and in fact any change, either from normal to alarm or *vice versa* will cause the transceiver to make a rotation and signal the latest position. Thus at each operation, complete information comes back to the control room. If at any time the operator wishes, he can initiate an operation of the transceiver so that his information is checked; the receipt of the 'normal' signals is proof that no faulty condition exists.

Any system of remote control relies on the connecting line which—as far as we are concerned—is usually the responsibility of the G.P.O. It is very desirable that the operator in the control room should know at all times whether the line is in good order. Should a fault go undetected for any length of time, a difficult position would certainly arise. The system we are considering is such that the integrity of the line is proved continually in the following way. The reading instruments rely on

the incoming signals, to give any reading at all—that is to say, failure of the line causes all pointers to go right off the working part of the dial, and the existence of a fault is at once obvious. Thus a glance at any one of the reading instruments will 'prove' the line. The equipment described above is, of course, only one example from many possibilities, although it is believed to be the only one designed specially for the gas industry. Reference to Table 1 shows that types 2a, 5a and 5b could all give the service required, but at present their use appears to be confined to other applications. If at some future date some combination of these types is sufficiently developed to become an improvement on the system already described, the writer hopes that he will be associated closely with this work.

DISCUSSION

Mr. A. Griffiths, Wolverhampton, opening the discussion, thanked Mr. Hancock for a most interesting paper and said that he had himself seen, in various parts of the country, examples of remote control mentioned by Mr. Hancock and these were, for the most part, operating quite successfully. He had noted, however, that these devices tended to be rather elaborate and felt that the same results could be obtained by simpler means. He had in mind the remote control of governors and boosters and considered that control by clocks, cams and cables was much easier and quite as effective. He thought that in the event of trouble developing, a visit to the site by a member of the technical staff was preferable to remote control by a single operator who was, of course, liable to human error. Mr. Griffiths enquired whether line faults could be kept at a minimum since in gas works practice, safety was always the first consideration.

Mr. Hancock, replying to Mr. Griffiths, said that he was strongly opposed to over elaboration in the use of control instruments. Where a station was unattended there was no point in sending messages by remote control unless it was necessary. He agreed with Mr. Griffiths that alarm systems should be such that safety was the first consideration—telephone lines were now very reliable as long as they were not overhead lines and most were now underground. It did not follow that a radio link would be more reliable and would probably not justify the additional trouble and expense.

Mr. S. C. Crathorn, Wolverhampton, also thanked Mr. Hancock for his paper and asked Mr. Hancock how he defined 'long' and 'short' distances in the sending of messages.

Mr. Hancock said that instruments operating within a works could be considered to operate over 'short' distances while distances of more than say two miles would be considered 'long' distances and a G.P.O. line would normally be required.

Mr. F. Dawson, Smethwick, thought that where a number of governors had to be controlled from a distance, the method demonstrated by Mr. Hancock would be very suitable, but he wondered what the cost would be.

Mr. Hancock said that the system he had demonstrated was quite a simple one in which the most costly item would be the renting of the G.P.O. land line.

Mr. S. A. Tait, Redditch, said that the holders situated at Bromsgrove were controlled from his works at Redditch. The important task of controlling stocks and pressures at Bromsgrove was done by telephone and there had been very little trouble with the G.P.O. land line. They had an arrangement by which in an emergency contact could be made by a G.P.O. line following a different route. Mr. Tait added that the drum and cable method of measuring the height of a holder was in use at Bromsgrove, but the cables were liable to snap.

Mr. Hancock said that of the two methods of measuring the height of a holder, viz., by drum and cable and hydrostatic head using a hose, neither was good but he preferred the former. It might be that some application of echo sounding as at sea would be developed in future. He suggested that the positioning of the pulleys in relation to the cables would repay careful study to minimise the risk of the snapping of these cables.

Mr. B. G. H. J. Hawkins, Coventry, said that he had had some experience of Walker, Crosweller & Co., Ltd., equipment and had found it to be quite satisfactory. He asked if it would be necessary for an instrument engineer to look after equipment such as that demonstrated by Mr. Hancock or could it be serviced by works technicians.

Mr. Hancock said that his firm did undertake servicing from their works at Cheltenham. The equipment he had demonstrated was not complicated and eminently suited for use on a gas works. Its maintenance was well within the capabilities of its operator since his firm prided themselves on the simplicity and reliability of the equipment they produced.

Mr. W. E. Dobson, Birmingham, said that during a recent visit to the U.S.A. he had been surprised to see the use of high frequency micro waves instead of the telephone and asked Mr. Hancock for his opinion on the subject.

Mr. Hancock said that if telephone lines could be run underground they were quite reliable, but where this could not be done, high frequency micro waves could be used with success. Even then, he could see no good reason for using what was inevitably a more complicated system in which more could go wrong.

Analysis of Coal

IN the revision of B.S. 1016:1942 the series of analytical and physical tests are now being issued as separate parts, of which the first five have already been published. Part 6, now issued, deals with the determination by specified methods of the major constituents of coal. Those referred to are carbon, hydrogen, nitrogen and sulphur. The Liebig method for carbon and hydrogen has been slightly modified in detail from that given in the 1942 edition and the use of oxygen only for combustion is now specified, particularly for a new high temperature (1,350°C.) alternative method. In the macro Kjeldahl method for nitrogen, the use of selenium as an alternative catalyst is now permitted; a quicker semi-micro Kjeldahl method has also been introduced. Copies of this Standard may be obtained from the British Standards Institution, Sales Branch, 2, Park Street, London, W.1. Price 10s. (Postage will be charged extra to non-subscribers.)

From a paper to the South Western Section of the I.G.E., Exeter, January 14, 1959.

Fifty Years in the Gas Industry

By Dr. ARTHUR MARSDEN, M.B.E., M.Sc., F.R.I.C., M.I.Chem.E., M.Inst.Gas E., M.Inst.F., C.G.I.A.

FIFTY years ago the entry of a person into an industry was far more fortuitous and environmental than is the case today, when the majority of entrants deliberately choose their profession of their own free will. We should also remember that the great expansion of British chemical industry, and I include the gas industry in that, has taken place within the last 50 years, and, perhaps regrettably, very largely through the necessity arising out of the country being involved in two great wars

We now live in a chemical age, although, until about half-a-century ago, the main interest in science was in so-called pure science, that is to say, science as knowledge, and the pure scientist had little desire to apply his knowledge to practical ends. But now all that is changed. In fact, we seem in danger of swinging too far the other way—I am thinking of the efforts spent on, say, space travel, when there is so much to do near at hand.

Later we shall consider education, but at the moment we should remember that 50 years ago there were few persons recognised as chemical engineers in this country, and there was no course of education provided to enable a man to qualify as a chemical engineer. It was not until 1918 that a chemical engineering groupwas formed within the Society of Chemical Industry, and later, in 1922, the Institution of Chemical Engineers came into being. I am proud to have taken some small part in the formation of both.

Taking the broad view, the gas industry is essentially a large-scale example of chemical engineering, and from that angle we have learned from the great and rapidly developing oil industry, which itself was quick to recognise the value of the chemical engineer; and that actually was a potent factor in laying the foundations of the science of chemical engineering in the United States of America.

Good Reasons

Perhaps the most impressive fact that has emerged during the preparation of these notes is that so many ideas, processes and plant which have been put forward as new or novel have been, at least in their essentials, tried before and rejected for what were, at the time, good reasons. At the time of my entry into the industry the horizontal retort reigned supreme, and you will remember that fireclay retorts did not come into general use until about 1850, although Grafton had introduced fireclay ovens as early as 1820. I can, of course, remember a few settings of C.I. retorts heated by 'direct' firing, but my first chief impression was of 'through' fireclay retorts in settings of 8, 9 or 10, and having the then famous 'Klonne regenerators.'

At one time or another I have had experience of all forms of charging and discharging plant for horizontal retorts, from shovel and rake to the latest combined machines, but it is a pleasant memory to have seen the first De Brouwer charger in this country start up. It was installed by Jenkins and was slung from an overhead runway, while the motive power was D.C., generated by a gas engine-driven dynamo. The combined charger and pusher soon followed, and, as long ago as 1910 we were collecting the coal-dust from the D.B. charger quite effectively, and selling it to the local foundries for moulding purposes.

Heavier Seals

Many of the modern operating instructions, particularly those relating to horizontal retort installations, are little different from those I remember prior to World War I, except perhaps those relating to pressure conditions in the retorts. Much heavier seals were used resulting in more scurf, while overpulling, when more gas was needed, frequently caused peculiar situations.

Attention to producers was, perhaps, more easily enforced on labour in those days, and then, as now, ascension pipes had to receive regular attention. They had to be cleaned from the bottom to the full length of the auger, which itself had to be maintained at a gauged size. It was not permitted to burn out pipes, and augers were not to be heated. About this time also the self-sealing lid had become established, although until a satisfactory maintenance system was introduced, they gave more trouble than the old lime-luted lids.

In those early days it was possible to buy good, clean, well-sized gas-making coals at competitive prices. Even so, a careful watch was kept on their quality, and although the method of testing was the same, that is a small 1/1,000 plant supplemented, as you will see later, in appropriate cases by large scale tests, the method of evaluation for gas-making was different. My entry into the industry was at a time when a kind of hazy no-man's land existed, and the 'candle versus calorie' controversy, as Professor V. B. Lewes called it, was beginning to take shape in the minds of gas engineers. As a result much work had to be done on determining the 'illuminating power' of gas and evaluating the 'sperm value' per ton of coal. Most of us have occasion to use the term 'candle power' from time to time, but not everyone today has seen a 'standard candle.' There were six candles to the pound made of sperm wax, and each burned (they were generally used cut into halves, both halves being placed in a candle balance) 120 grains or 3/175 lb. per hour, the permitted limits of variation being 63 or 57 minutes for which corrections were

made. For coal evaluation in pounds of sperm per ton, the calculation was simple: —

$$\frac{\text{cu.ft. of gas per ton} \times \text{illuminating-power in standard candles}}{5} \times \frac{3}{175}$$

The illuminating power determination involved some rather elaborate equipment, based of course upon the Bunsen grease-spot photometer, and the inverse square law. There were timing arrangements, means for weighing the burning candles, and controlling and measuring the gas, which had to be burned at the rate of 5 cu.ft. per hour. Of course, all extraneous light had to be excluded. Later, the sperm candles were superseded by secondary standards such as the amyl acetate and pentane lamps. Eventually the Bunsen disc was replaced by the rotating flicker-head and an 'aged' electric lamp, run from an accumulator was used as a standard. These two changes were particularly useful for portable photometers, and the flicker-head also enabled measurements to be taken of light sources not in a horizontal line with the standard, such as arc lights and h.p. gas lamps. There was some interesting work to do going round in the evenings with a portable photometer comparing the behaviour of electric and gas lamps in the streets.

There were also important changes in the standard burners, in which the gas to be tested was consumed, the general goal being to obtain more 'candles per cu.ft.' For instance, the London Gas Act, 1905, required among other things, a test for illuminating power by a flat flame burner to be prescribed by the gas referees. As a digression it may be noted that the referees were J. S. Haldane, 1899-1936; W. J. A. Butterfield, 1917-1938, and Sir Charles Boys, 1897-1938, all of whom I was privileged to know.

Various argand burners had been in use for testing gas, and the dimensions of the various parts were rigorously controlled, particularly the holes in the steatite head. The final burner in this class was the Carpenter No. 2 Metropolitan argand, 1905.

Incandescence Burner

Consider for a moment the impact of the incandescence burner. Bunsen had invented the atmospheric burner in 1855, and in 1884 von Welsbach patented the use of rare-earths for use in mantles, although the first satisfactory mantle was not on the market until 1891. Recuperation was applied to inverted burners in 1903 and, in 1907, Keith and Blackman introduced high-pressure gas lighting. The invention of the incandescent mantle reduced to one-eighth the amount of gas needed to produce the same amount of light as a flat-flame, and, for a while, the inroads of electricity for lighting was halted. Mantles were sold by the million and all types of burners made, particularly in Germany.

Let us return to carbonising plant for a moment. In 1902 Settle and Padfield introduced a retort of which the upper portion was vertical and the lower portion bent so that the discharge door projected through the side wall of the setting. Coal was charged continuously and the coke removed intermittently. Thomas Settle was a man whose ideas were well in advance of his time, and about 1910 I worked for a while with him in Leicestershire; it was a most rewarding experience.

Also in 1902, Dr. Bueb obtained a patent for a vertical retort from which the gas was removed through the side wall. Later on he developed the Des[illegible]au intermittent vertical retorts, and one of the earlies[illegible] installations in this country was at Ayres Quay, Su[illegible]derland. Sir John Bell, who was a friend of Charl[illegible]s Drury of Sunderland, was interested and arranged t[illegible] have a large-scale test on Derbyshire coal, several tr[illegible] in loads of which were used. I spent several useful [illegible]eeks on that work. The inclined retorts of M. Coze, [illegible]f which there were a number of examples here, event[illegible]ally fell before the onslaught of the continuous vertic[illegible] retort. The inclined retorts were difficult to control and the heating often irregular. The old horizontals, particularly with the impact of the Clean Air Act, are an unconscionable time a-dying through amortisation, and although they are doomed, about 20% of the coal gas in Great Britain is still made in them, as against 38% in continuous vertical retorts, and 5% in intermittent vertical chambers.

Refractory Materials

Before leaving the subject of carbonising plant we should give some consideration, if only briefly, to refractories. It was in 1908 that F. J. Bywater presented the first paper on refractory materials to the Institution of Gas Engineers, and that fact probably had much to do with the formation in 1910 of the Refractory Materials Joint Committee. Much valuable and fundamental research work has been carried out over the years and the names of Mellor, Green and Roberts, among others, come immediately to mind. Perhaps the most outstanding result has been the increase in useful life of gas-works refractories, and although as Roberts pointed out recently, the best performances of 20 years ago may be better than the worst still encountered, depending perhaps on operating control, on the average the expectation of retort life has just about doubled in the last quarter of a century.

By the end of the last century crystallographers had observed that silica exists in three principal forms, quartz, cristobalite and tridymite, and it had also been noted that, when heated, each form converts to a different state of symmetry. Roberts has reported that when kinetic measurements were made recently of the rate at which quartz transforms into the other forms of silica, a new feature was revealed, namely, that the quartz does not seem to go directly to cristobalite and tridymite but to an intermediate phase from which these other two forms are derived. The delay on discovering this fact appears to be due to the previous absence of suitable techniques and it is not yet known what practical bearings the new knowledge may have. In the meantime further research continues to elucidate the remaining problems of 'flaking' and 'spalling.' In addition, as the industry turns to the increased processing of oil products, there will be further work to do on the attack of carbon and inorganic constituents of the oil on the refractories under conditions of load and thermal shock.

Casting my mind back, I recall trouble with segmental horizontal retorts, due to the effects of swelling coals and the efforts of discharging machines, but that trouble was not, of course, due to the properties of the refractories themselves.

Passing lightly over condensers, where I saw the

atmospheric type replaced by the annular and finally by the thermostatically controlled water-tube type, and the exhausters, of which most were of the Beale two-bladed type, later replaced by the multi-blade, to reduce oscillation, and then by the turbo- and Connersville types, we will turn to a subject of considerable importance, namely, sulphur. I propose to review that problem in conjunction with purification, by-products and effluent disposal. It also had, and still has, an important bearing on gas quality and distribution problems.

Incidentally, the introduction of fireclay retorts, with the resulting higher carbonising temperatures, and particularly when, as was usually the case, the retorts were lightly charged, caused immediate and widespread trouble due to naphthalene deposits. This hydrocarbon, which is a high temperature product, crystallises readily in very thin plates which obstruct everything from the retort house to the consumer's appliance. Naphthalene, or 'salts' as it was called, together with water deposits, because gas was not 'dried' until about 25 years ago and gas fitting often left much to be desired, brought into being the 'man with the service cleanser.' In order to ensure an adequate and non-fluctuating supply, many consumers sent off postcards at regular intervals and, as a matter of course, asked for the service to be 'blown.' Also, I have a clear recollection of one large works where the mains leading to the holders were fitted with manholes and, periodically the naphthalene was removed by wooden scrapers and carted away like snow. All this, of course, led to vigorous attempts to combat the naphthalene nuisance and various processes, such as the Derby naphthalene process, on which I worked, the Leicester process, due to Colson, and others were evolved, while eventually the oil-washing process, with or without benzole recovery, became almost standard practice.

When considering purification in the early days, two points should be borne in mind: (a) The illuminating power of gas; and (b) the sulphur clauses of the various Acts. In my early days, and even later, the peak loads caused great anxiety, particularly during fogs because the peak was not due to the heating load as it is today, but mainly to lighting. It was a soul-destroying business standing by the holders watching the time and counting rivets!

Gas Odorisation

It was the custom in those days to keep carbonising plant under 'slow-fire' for such emergencies, and it was also considered that the holder capacity should at least be equal to the output of the maximum day. Even so, it was not unusual to 'over-pull' on the retorts, and to drop district pressures. I can also just remember at one works a store of cannel coal which was kept for boosting the candle power of the gas during emergencies. Carburetted water gas plant was only just getting into its stride, and many works relied for candle power control on carburettors, which were steam-heated vessels in which various hydrocarbons were volatilised into the gas stream. A number of liquids were on the market but most frequently benzole was purchased, while condensate from the nearby railway oil gasworks was also used. The thought of that evil-smelling liquid brings to mind the question of the odorisation of gas.

For many years the law has required that gas should have the 'distinctive pungent smell of coal gas,' but this was amended in 1951 to read that gas 'should have a distinctive smell.' Recent work (Gas Council Research Communication GC59) has indicated that tetrahydrothiophen is the most promising odorant at present available because, while the mercaptans are more odorous, they are nauseating and, more important, they fatigue the sense of smell more quickly.

Turning to the sulphur clause question, we may recall that from 1851 to 1840 Clegg's lime-water purifier was in common use—the earliest perhaps of the numerous attempts, still being made with increasing success, to purify carbonisation gas by liquid reagents alone. The objectionable effluent caused the process to be abandoned in favour of layers of slaked lime, introduced by Phillips. As long ago as 1866 Sir George Livesey introduced the idea that gas could be made free of its impurities without the use of solid reagents and entirely by liquids. I entered the industry at about the changeover time, and the various works had a combination of lime and oxide purification, although within a year or so oxide purifiers, comprising deep boxes, dry-lutes with spur-wheel tightening gear, and Millbourne valves had all been introduced. The evil-smelling spent lime or 'blue-billy' was quite a problem and special precautions had to be taken when carting it through the streets. It was stored, allowed to oxidise by weathering, and then used as an agricultural fertiliser.

Use of Oxide

It was in 1849 that Hills obtained a patent for the use of hydrated oxide of iron for the removal of hydrogen sulphide from gas, and in 1852 he had a further patent for 'renovating'—revivifying as we call it now—the used material with air. There were two reasons why the use of oxide did not expand very much until the early years of the 20th century: (a) Sulphided lime absorbed carbon disulphide from the gas to form a thiocarbonate, and thus helped the undertakings to comply with the Metropolis Gas Act of 1860, which required that the gas, after purification from hydrogen sulphide, should contain less than 20 grains of sulphur compounds per 100 cu.ft. As will be readily imagined, sulphur determinations by the referees' methods formed a considerable part of routine control in those days. This limitation was repealed in 1905, after which lime was replaced by iron oxide. (b) The slaked-lime also removed carbon dioxide from the gas, thus raising its illuminating power. In general there was a loss of about .3 candle for each 1% by volume of carbon dioxide. Incidentally, the working of a system of lime purifiers needed great care because carbon dioxide displaces hydrogen sulphide from sulphided lime.

In connection with (a) above, I might refer to another example of the way Sir John Bell looked ahead. Although the sulphur clause has been repealed he felt, quite rightly, that the sulphur content of the gas should be kept as low as possible and, knowing that carbon disulphide is produced chiefly in the retorts by the action of other sulphur compounds upon red hot coke, he examined the effect of reduced time contact. About that time, 1910, an ascension pipe at one end of the retort only was being advocated, and an opportunity was taken to use the two retort houses at the Litchurch works as test plants. The gas from the two houses

could be isolated and purified separately, and so one was worked with two ascension pipes per retort and heavy charges while the other had one pipe in operation on each retort and lighter charges. It was very interesting work and showed that the reduced time contact lowered the organic sulphur content of the gas by several grains.

The long-suffering purification process using hydrated iron oxide is something which should command admiration, because for many years it has worked in spite of frequent ill-treatment. The process labours under many disadvantages, among them the necessity to purify gas to the referees' standard, the necessity to produce a spent oxide having 50% (DB) sulphur to be reasonably saleable, the large ground space required, and the fact that, in effect, only half the plant is working at any given time. In addition, there is the growing shortage of suitable natural 'oxide,' and also the objectionable working conditions during the emptying of the purifiers. Strangely enough, the changes in procedure during the past 50 years have, apart from the adoption of overhead purifiers and mechanical handling, been crowded into the relatively recent past. The tower purifiers represented a definite attempt to control the process much more closely, while dynamic methods, coupled with the use of artificially prepared purifying medium of constant quality, and the extraction of the sulphur by means of suitable solvents, thus enabling the material to have a longer useful life, are all important steps forward.

Meantime much work has been carried out on old conventional plant to define the conditions necessary to prevent hardening of the oxide and to obtain, in effect, increased purifier capacity. No doubt one of the greatest contributions to this end can be made by closer control of the wet purification plant preceding the purifiers. By close control, 'tar fog,' objectionable hydrocarbons, excessive ammonia and a reduction in cyanide can all be achieved. The large fluctuations in the 'blue' content of spent oxide indicate the need for more control. There is, of course, nothing new in this because I recall that years ago spent oxide, although nominally sold on sulphur content, actually had its price fixed on 'blue.'

Recovery of Cyanide

There have been various processes worked for the recovery of cyanide, most of them operating on the spent oxide to obtain prussian blue, but a few washing the gas for the removal of hydrogen cyanide, which I consider the correct way. Of these processes the Davis-Neill operated in Great Britain, the first plant being at Linacre, Liverpool, while the second, erected in 1909, was at Derby and, together with a large sulphate of ammonia plant and a Simon-Carves concentrated liquor plant gave me my first insight into chemical engineering. It may be noted that the sulphate plant had bottom-discharge 'saturators,' a new development in those days, since most were of the 'fishing' type. This advance was due largely to C. Stafford Ellery, of Bath, and in late 1913 I was operating his original saturator.

The Derby 'prussiate' plant, as it was called, introduced me to the then relatively new Kestner 'climbing film' evaporator, which fascinating process produced a very high grade of sodium ferrocyanide, the final concentrated solution being allowed to crystallise on rows of inverted 'U's' of rope suspended in large lead lined wooden tanks; the clusters of crystals looked like large yellow sugar candy. The product was handled with wooden shovels because any contact with iron resulted in a stain of prussian blue. The process was eventually closed down when it became uneconomical on account of the competition from other sources of sodium cyanide.

The removal of hydrogen cyanide from gas is a matter worth renewed consideration because, not only has its presence a very adverse economic effect on oxide purification but, if it passes the purifiers, it is a potent factor in plant and main corrosion. In fact, in the U.S.A., in at least one large plant, it was decided to remove it on that account, and to find a market for the product afterwards. That did not turn out to be particularly difficult because about that time cyanides became important raw materials in the plastics industry. The interesting development I saw was at Kearny, N.J. (U.S.A.), where a plant had been erected in 1951 to recover about two tons of HCN daily from the carbonisation of 4,000 tons of coal in coke ovens. The plant appeared to be relatively trouble free and the extreme safety precautions necessary when numbers of tanks, each containing 500 gal. of 99.6% pure liquid prussic acid, were quite an education.

Alarming Experience

Returning now to oxide purification, a word should be said on the control of air for revivification *in situ* because procedures are still far from satisfactory in many cases. If the air is admitted at the condensers it may, among other things, cause the formation of relatively large amounts of thiocyanate. Incidentally, I recall an alarming experience in 1913 which was brought about by the accidental admission of air in excessive amounts at the condensers. In those days it was the practice to use the Harcourt colour test each morning and afternoon to control the operation of purifiers, and one day the sulphur content of the gas at the outlet of purifiers rose in 3½ hours from 45 grains to 250 grains per 100 cu.ft. This was found to be due to a purifier charged with active 'Lux' oxide being actually on fire, and the high sulphur figures were due to sulphur dioxide. The purifier was isolated and after cooling and opening up, which was a risky business because purging was not carried out in those days, it was found to contain a thick surface layer of nearly pure sulphur which had been sublimed out of the mass.

This occurrence finds a parallel in the process which F. G. Andas developed a few years ago in which sulphur dioxide in slight excess of theoretical requirements is added to the gas and allowed to react with the hydrogen sulphide on a catalyst, usually alumina at temperatures between 30° and 90°C., the temperature being maintained by the heat of reaction. Sulphur is deposited on the catalyst which is withdrawn continuously for regeneration by heating to 500°C.

It does appear that when existing box purification systems have completed their useful life, they will be replaced by dynamic systems, and eventually by some satisfactory liquid system which will emerge from all the work and effort being put into those now being tried out. When increasing volumes of gas are made, under pressures of several atmospheres, some liquid purifica-

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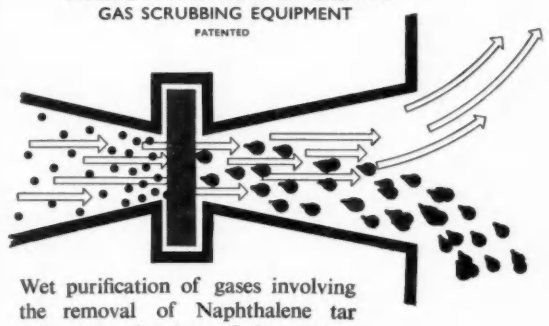

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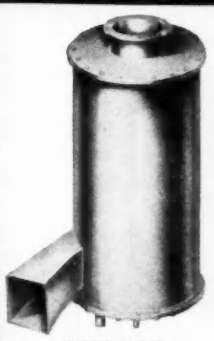

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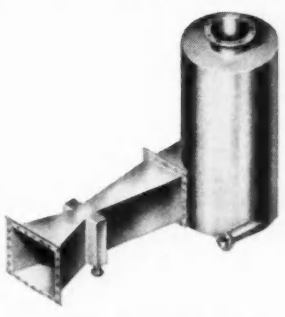

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tion process will come into its own if only because the iron oxide process does not operate satisfactorily at high pressures. There will also be the need to remove the two acid gases, carbon dioxide and hydrogen sulphide, separately, and independently so that the possible use of certain organic dyestuffs, in particular methylene blue (Davis, Mills and Ryder, I.G.E. Communication GC45, 1958), will be followed with interest.

More Sulphur

Meanwhile sulphur in its elemental form is always likely to command a higher price than when in the form of spent oxide. Increasing amounts of sulphur are becoming available from oil and natural gas and near at hand, for example, the relatively new Lacq field in South-Western France is already producing 70,000 tons of sulphur per year from 1 mill. cu. m. of gas per day. The world sulphur situation changes rapidly, and while a year or two ago there was a shortage, as recently as November, 1958, sulphur was priced at about £8 per ton, and was stated to be at a depressed level. It was also asserted that as a result of diminished interest, production of all forms of sulphur would be hard pressed to meet rising world needs, which by 1967 were estimated to exceed 24 mill. tons. The present price of sulphur is only 30% higher than in 1937 during which time the price index of general chemicals has risen by 70% and steel prices by 175%. Whatever the price of sulphur, the gas industry will have to remove that element from its gas and so contribute to a cleaner air.

People in high places have given much lip service to the subject of sulphur removal, but only a few pioneers have made definite attempts to get something done. The former South Metropolitan Gas Company commenced using the Carpenter-Evans process in 1910, and I remember giving a talk upon it, as an example of industrial catalysis, to the Society of Chemical Industry at Bristol in 1921. My own view, often expressed, is that if the gas industry cannot afford to remove sulphur compounds from gas, then it cannot afford to push the sale of flueless appliances because—and this is important—there is no sulphur problem for the consumer who chooses electricity, butane, propane or paraffin as his fuel. In this situation it is very encouraging to read the recent pronouncement of the Chairman of the South Western Gas Board to the effect that within three years the whole of the Board's area will be supplied with sulphur-free gas.

It is well known that certain oil feedstocks are virtually sulphur-free, but for a long time to come our base-load gas will come from the processing of coal; fortunately complete gasification processes will by their nature help with the sulphur problem. Meantime with conventional coal gas and C.W.G. we shall have to use a combination of oil-washing and catalytic removal. This is perhaps convenient because, quite apart from benzole recovery, the plant is usually available for naphthalene removal and the extraction of unsaturated hydrocarbons which may condense in purifiers, polymerise, and reduce the efficiency of the oxide for purification.

It should also be noted that the organic sulphur present in the gas as carbon oxysulphide is not readily soluble in wash oil, and this is an important factor in setting a limit to the effectiveness of the oil washing process, which is of the order of 50% removal of organic sulphur. To be really effective the wash oil process must involve over 90% benzole recovery, and thus a calorific value depression of 30-35 B.t.u. per cu.ft.; and this means either the initial production of a richer gas or 'defronting' the extracted benzole, and its return to the gas. The weakness of this procedure is that while removing practically all the carbon disulphide in the 'fronts,' the thiophen is returned to the gas with the 'defronted' benzole since the two, benzene and thiophen, are not separated by distillation. The catalytic process removes the carbon oxysulphide readily, although there is more difficulty with the thiophen. However, the catalytic process possesses another great advantage in that the nitrogenous gum-forming nitric oxide is removed completely, and the value of that is incalculable.

The extent to which it is necessary to reduce the sulphur content of gas is a matter of considerable importance because during the burning of gas—and coal gas is intended here—the organic sulphur compounds which consist essentially of carbon disulphide, thiophene, carbon oxysulphide, and mercaptans, produce sulphur dioxide and trioxide in a ratio usually varying between 3 to 1 and 5 to 1 by volume. This is important because sulphur trioxide becomes perceptible by smell when present in an atmosphere to the extent of .0002% compared with .0002% for sulphur dioxide; strangely enough the threshold of perception for the mixed oxides is .0001%, or 1 ppm.

The concentration of sulphur oxides in the atmosphere of a room heated by a flueless gas appliance depends on (a) the sulphur content of the gas burned, (b) the rate of gas consumption, (c) the volume of the room, (d) the rate of air change in the room, and (e) the absorption of sulphur oxides within the appliance, and by the walls and furnishings. The report of the Royal College of Physicians, issued in 1936, assumed 50% absorption by walls and furnishings, and accordingly considered that the ultimate objective of the gas industry should be a sulphur content not exceeding 3 grains per 100 cu.ft. With such a gas burning in a room at the rate of 1 cu.ft. per hour per 100 cu.ft. of space, in which there is half an air-change per hour, there should be no perceptible odour due to the products of combustion.

Effect on Appliances

Let us now turn for a moment to the effect on appliances. In the case of experiments with instantaneous water-heaters the main factor investigated (I.G.E. Research Meeting, 1946, Communication GRB27. Booth *et al*) was the sulphur content of the gas burned. It was found that when the sulphur content of town gas was reduced from 17 to 3 grains per 100 cu.ft. there is an almost corresponding reduction in the amount of corrosion. An experiment using gas containing .1 grain of sulphur per 100 cu.ft. gave considerably more corrosion than when the gas contained 3 grains. It was concluded that there is probably a value for sulphur content below which corrosion tends to increase again. This value is probably about 3 grains.

The presence of sulphur trioxide in flue gases also causes their dewpoint to be raised by an amount which

increases as the excess air in the gases decreases, and so the tendency to condensation is increased. Condensation of flue gases is often deleterious to flue or chimney materials of construction.

Increasing attention is being given to the cleanliness of works and the abatement of nuisances. In the earlier days of the industry dust, smoke and smells were, in general, accepted as being inseparable from gasworks, and that may have had something to do with the music hall jokes, many of which are still current. The improvements of recent years have had various causes, and there is still much to be done. In 1949 Wissman gave an assessment of the main dust problems in gasworks practice, as follows:—

	Dust deposited per day (tons).
1. Coal handling—1,200 tons from ship to retorts at 1 lb. of dust per ton of coal	0.50
2. Coke handling—750 tons coke from retorts to producers, C.W.G. plant and sale, at 18 lb. of dust per ton of coke	6.50
3. Flue-dust from waste gases in retort settings at .6 lb. per ton of fuel ...	0.05
4. C.W.G. 'fliers'—5.0 mill. cu.ft. C.W.G. at 500 lb. of 'fliers' per mill. cu.ft.	1.10
5. In raising 60 units of steam at 30 lb. dust per unit	0.80
	8.95

It will be seen that there is no mention of 'dust' from breaking and handling oxide, a procedure which still leaves much to be desired on some works.

Presence of Germanium

Certain dusts can be made to yield an income, and here reference must be made to germanium because although certain aspects of its occurrence and use are now common knowledge, there are several new ones. It is well known that the existence of the element germanium was predicted by Mendeleeff in 1871, and actually discovered by Winkler in 1886. Incidentally, no specific physiological effects of germanium are known. Coal ash has long been a happy hunting ground for trace elements and during their formation, and in some cases perhaps later, coal seams appear to have acted as concentrating agents for a number of rare elements. Goldschmidt, in 1930, examined Hartley Main (Northumberland) coal for the presence of trace elements, and reported gallium and germanium, while in 1937 Morgan and Davies worked out a process for their recovery. The presence of germanium in coal in this country varies from .05 ppm. in the South Wales coalfield, to as much as 50 ppm. in Durham, with an average for the whole country of about 7 ppm., and a tendency for the germanium to be higher near the roof and floor of the seams.

Recent figures show that gasworks produce, about, 5 tons of flue dust, with an average germanium content of .5%, per mill. tons of coal carbonised. It is now possible to sell flue dust with a germanium content of .1%, but with the increasing demand for the metal attention is now focussed on the ultimate distribution of the element, originally present in the coal in the various products of carbonisation, and on means for increasing the amount recovered. It has been found that germanium will normally be volatilised from a coal or coke only if combustion of the carbonaceous material also occurs. This would explain the comparatively small proportion of the element volatilised during coal carbonisation.

Tests on three coke oven installations employing different methods for the recovery of ammonia showed that about 8% of the germanium in the coal is volatilised during carbonisation, and almost all of that was found in the tar and liquor. There was no evidence of appreciable amounts passing the tar extractors, and neither is the germanium appreciably volatile during the distillation of liquor; most of it remains in the still effluent. Up to about 5% of the germanium in the coal finds its way into the effluent, but since its concentration in the still effluent or in ammoniacal liquor is only of the order of a few ppm. it is not yet proved that its recovery would be an economic proposition. However, it has now been claimed that not less than 90% of the germanium in ammoniacal liquor can be recovered by the use of a germanium-tannin complex.

Tests made on a setting of continuous vertical retorts (D.S.I.R. Fuel Research Report, 1957) have shown that normal day-to-day variations in the operating conditions have an important influence on the proportion of the total germanium driven off from the fuel bed. In three tests the sums of fractions retained in unburnt coke, clinker and ashes were 26%, 15% and 34% of the germanium originally present in the coke. Where there was no disturbance of the material deposited in the flues, between 50% and 60% of the total germanium was present in the gases entering the chimney. Only about 10% to 15% of the total germanium is contained in the type of flue deposit which is left undisturbed for long periods.

The work has produced further evidence in support of the belief that the germanium is present in the flue gases largely as an aerosol, and the possibility of collecting particulate matter containing germanium from flue gases on a commercial scale is difficult because of the very small size of the particles and the low concentration, which is about .01 grain per cu.ft. of flue gas.

Since no precise sequence of plant and process has been adopted in these notes, we may now turn to the question of gas storage. When I first entered the industry holders were all column guided, and mostly of relatively small capacity. In some cases the counterbalance weights had only recently been removed, but at Litchurch, the works recently reconstructed by the East Midlands Gas Board and originally built well and spaciously, by Thomas Hawksley, two holders of about 2 mill. cu.ft. capacity were modified about 1910, and in each case a so-called 'flying lift,' which rose above the guide framing, was added. A year or two later, at Belper, a spiral-guided holder was built.

Construction and Maintenance

Our ideas concerning the capacity, construction and maintenance are undergoing constant change. Gasholders are costly to construct and maintain, and are not necessarily things of beauty, so that the tendency will be to reduce their size and numbers, with in suitable cases a trend towards high pressure or even underground storage. In this we may follow, to some degree, American practice, for even in 1952 78% of the gas distributed in the U.S.A. did not pass through a gasholder. We cannot emulate them in 'line pack,'

neither do we possess known depleted oil or gas fields in the country. While the search for natural gas has not yet led to satisfactory results, only small amounts having been found, the drilling may disclose underground structures suitable for storing gas at high pressures.

One need only refer to the experiment in the north-east to store about 10 mill. cu.ft. at a depth of 1,170 ft. in a salt stratum. It has been estimated that the cost of preparing the underground storage would be only about one-fifth of the cost of equivalent holder capacity above ground. In the case of American practice reliable figures for loss do not appear to be available. Perhaps they are not of vital importance since the gas might have been flared or blown-off if not stored. But in the country where the cost of manufacture per therm is relatively high, the unaccounted-for gas must be kept low, and so there is need to obtain definite information concerning the thermal loss that may result from the storage of manufactured gas in underground geological formations.

Speaking of gasholders and gasworks plant generally, one great advance that has taken place over the years has been the gradual but sure introduction of planned maintenance, which is now understood to commence with installation and not with break-down! In addition, considerable attention is given to safety precautions to protect both personnel and plant, and these will increase in importance as mechanisation and automation are extended.

The question of gas storage leads one to think of distribution, and utilisation. It is not possible in this paper to consider the changes that have taken place in main and service laying in the last 50 years. They have been numerous, and in some cases profound, but mechanisation and the protection of pipelines and other structures against corrosion are the outstanding advances of recent times.

Lacks Glamour

Distribution engineering has, I feel, tended to suffer in the past because it lacks glamour, but when we consider that the industry has been putting up to £20 mill. a year of capital into the ground, its importance becomes clear. One also wonders whether sufficient forward thinking has been given to the possible future use of higher pressures, and to the regard for conditions outside the frontiers of any given area board. Under the impact of the latest developments in gas-making it seems that a national gas grid will be desirable. In fact some think it already belated, and we may remind ourselves that on the Continent a continuous high pressure grid stretches from Paris to Hanover.

A national grid will also be necessary as and when more gas is produced from oil near refineries or becomes available at ports. One important point to bear in mind is that it is cheaper to transport gas at high pressures through mains than to distribute electricity by high voltage cables, and of course, much cheaper than carrying coal by rail transport; thus complete gasification plants may be erected near the pithead.

The changes that have taken place in utilisation deserve a paper to themselves. I have seen, for all practical purposes, the end of gas as an illuminant, and also the virtual disappearance of the gas engine, which at one time was the cheapest and most convenient form of obtaining small power supplies—in fact it provided quite an important part of the industrial load.

An interesting story could be told of the chequered careers of the various by-products of the gas industry, but space can be found for only a few salient features. Beginning with tar it may be noted that in the very early days of coal carbonisation the disposal of tar was a grave problem and much of it was burned as a fuel—a modern parallel is provided by the present-day pitch-creosote mixtures—but later creosote for treating railway sleepers was in heavy demand, as also was pitch for briquetting. Immediately before the 1914-18 war the question of the use of tar for road-making came to the fore and a number of tar dehydration plants were erected on gasworks, to produce tars to certain specifications. Later most of these disappeared as the, now almost universal, co-operative tar schemes developed.

Coal and Oil Tars

There is today a tendency for the production of coal tar to diminish and to be replaced by a variety of oil tars. From figures published recently it appears that the quantity of coal-tar produced in the U.K. for the period April-June, 1958, was 2% below the previous year. An interesting swing in the use of creosote from a raw material for hydrogenation to that of a fuel was reported in September, 1958, when the production of petrol at Billingham (I.C.I.) ended. The first petrol was made there 23 years ago, and since then 750 mill. gal, have been made, primarily from creosote. Changes in the pattern of requirements resulted in the petrol plant being 'run down' and switched to the treatment of raw materials derived from the new cracking plant at Wilton. On the other hand, as an indication of the different conditions in various places, by 1963 Australia hopes to be producing 80 mill. gal. of synthetic petrol annually from brown coal.

Before the first world war it was not usual practice to extract benzole at gasworks, but in 1915 toluene extraction from coal gas was started as a wartime measure. However, prior to World War II, the gas industry in Great Britain produced 20 mill. gal. of benzole per annum, although the actual amount of benzene in it tended to fall as the number of C.V.R.'s increased. Economic and other factors have caused the extent of benzole extraction to fluctuate over the years and at present it is falling, the April-June production in the U.K. for 1958 being 3% lower than for 1957.

The chief by-product, coke, presents a problem which will be solved only by an evolutionary, not a revolutionary, process. No one will deny that the gas industry has an immense part to play in the implementation of the Clean Air Act but, apart from preventing the emission of visible smoke, the nation will have to face what is perhaps the more serious aspect of the problem, namely, that of gaseous pollution by oxides of sulphur.

Of course, atmospheric pollution is not new, but what does appear to indicate a different approach is the determination, at long last, to do something about it. We are often told what Gladstone said, but here is a quotation from a speech he made in 1864, when Chancellor of the Exchequer: '. . . . if it were possible effectively to suppress what I must even venture to

call "the smoke nuisance" it would be a saving of many millions a year to the population of the Metropolis alone.'

The Beaver Committee Report of 1954, 90 years later, states that the cost of air pollution, excluding the value of the fuel lost through incomplete combustion, is estimated to be £250 mill. per annum in Great Britain. There is in addition the factor of human suffering caused by smog which it is not possible to assess in financial terms. Even at the present time in one square mile of a town it is not uncommon for a ton of coal to be burned every minute and estimates show that over 8 mill. tons of atmospheric polluting substances are emitted each year in Britain by the combustion of coal and its derived fuels, including coke.

In the early days coke was regarded as 'the poor man's fuel'—in fact I feel that it still suffers from that slur although its price today should have altered all that! It may be noted here that, among other things, the manufacture of carburetted water gas, has been used to regulate the coke market, because even as long ago as the 1880's surplus coke stocks were exported from this country.

During the time I have been connected with the gas industry the evolution of modern plant for the manufacture of C.W.G. has taken place. The water gas reaction had been known for many years and the first record of a practical process in England was in 1831 when George Lowe had a patent whereby hot coke was discharged from a horizontal retort direct into a water gas generator, and then heated intermittently by natural draught and 'steamed' to give blue water gas.

One-fuel Policy

From 1874 many oil-enriched blue water gas plants were built, and another Lowe, no relation of George, produced the forerunner of the modern C.W.G. plant in 1874. Humphreys & Glasgow became a British limited company in 1912 and the first world war gave an impetus to thermal efficiency and automation. Now it is safe to say that the gas industry is moving towards a one-fuel policy and away from the processes that yield one fuel as a chief product and another as a by-product to be sold for what it will fetch. That is why the 'gas plus coke' service, beset as it is by strong competition from electricity and oil, is in danger of being priced out of its traditional markets.

Coking and gas coals have been rising in price even faster than coal and will, I imagine, continue to do so. So far as can be seen at present, complete gasification offers the best way of bridging the gap between the only indigenous fuel Britain can produce and the kinds of fuel that modern consumers prefer.

To round-off the subject of by-products, ammonia and effluents must be included, because the picture with respect to ammonia has become progressively darker since World War I, while in recent years the question of effluents has become a matter of increasing urgency. As is well known, in this country the Rivers Board Act of 1948, has been supplemented by the Rivers (Prevention of Pollution) Act, 1951, which makes it an offence to cause or knowingly permit any matter which is poisonous, noxious or polluting to enter a stream. The new Act also empowers the river boards to prescribe standards for effluents. Until August of 1958 the boards could not institute proceedings without Ministerial consent, and even since that date it is only permissible to discharge a trade effluent into a stream or river provided there is no other reasonably practical way of disposal and all reasonable steps to render the effluent innocuous have been taken.

It is becoming increasingly difficult to satisfy the authorities on these points. When considering the question of effluent disposal it is necessary to remember that some of the latest methods for making gas, such as complete gasification of coal and the gasification of oil, produce effluents which are not suitable for application to the land and, by reason of their properties, are difficult to dispose of via sewers. It is now becoming widely recognised that questions of effluent disposal will have to be considered primarily within the works producing them, so that they can be re-used, re-circulated as an integral part of the process, or treated in such a way that an irreducible minimum of acceptable material remains to be discharged to the sewer or river.

Electrostatic detarring is a relatively recent development and an extension of it, hot gas detarring, is very useful for reducing the so-called higher tar acids in liquor because they are not volatile in steam and so tend to condense with the tar. If the suspended tar is removed from the gas before it reaches the primary condensers, then the H.T.A. remain in the tar and, if that tar is kept apart from aqueous condensates, then the liquor is much more readily acceptable for disposal.

The H.T.A. are particularly undesirable because, with the exception of catechol, they are resistant to biological oxidation. They are also responsible for forming strongly coloured solutions. Liquor from continuous vertical retorts contains a relatively high proportion of H.T.A.

Much research work has and is being carried out on, among other aspects, a comprehensive study of liquor constituents by the University of Leeds and the Gas Council. By far the most promising method of treatment, from the economic point of view, is by bacteriological oxidation and treatment at the gasworks as an alternative to disposal in a sewage treatment plant, and this will most likely become an integral part of the gas-making process and will be a part of the normal operating cost.

Nitrogenous Fertilisers

Turning for a moment to nitrogenous fertilisers, we may look back and remark upon the emergence, during the inter-war years, of chemical concerns whose activities were on a sufficiently large scale to be economically significant to the nation. Some of the distant underlying contributory causes for this were that the sales duty was abolished in 1825 and this was followed a few years later by reductions in those on glass and soap. This gave a great urge to the heavy chemical industry and made easier the advent of fertilisers. At Guessen, von Liebig (1803-1873) worked on agricultural chemistry and his results, though incomplete because he underestimated the role of nitrogen, were epoch making. His 'Familiar Letters on Chemistry,' published in 1844, had a considerable sale in this country.

In particular he drew attention to the importance of

phosphatic fertilisers and one of his students, J. H. Gilbert, later of Rothamsted, recommended the use of mineral phosphates. They were rendered soluble by treatment with sulphur acid and the first works to prepare superphosphate was started at Deptford in 1843, although a bone fertiliser works, still operating in a modern way, started up in Bristol in 1812.

All this fertiliser work had an important bearing on the nitrogen question and Britain began importing guano on a large scale in the late 1830's, and the consumption of nitrogenous fertilisers grew rapidly, Chilian 'saltpetre' being added to the list soon after 1850.

Waste Product

About this time the ammoniacal liquor from gasworks was a waste product, although some London gasworks were selling sulphate of ammonia; as late as 1871 the world production of this fertiliser was only 42,000 tons. Thereafter it rose quickly, and by 1900 about 500,000 tons annually came mainly from Britain and Germany. The synthetic ammonia plants following World War I really started the decline in value of by-product ammonia. The price of sulphate of ammonia was £20 per ton in 1880, £16 in 1917 and £7 in 1938, so that from being a useful factor in reducing the price of gas, ammonia has almost become a charge on the process. In an endeavour to avoid the national loss that would be represented by the waste of by-product ammonia, attempts have been made to extend rapidly the use of ammoniacal liquor as a direct fertiliser.

Two other important changes have taken place in general plant operation, including the gas industry, during the past half century. One relates to a more efficient use of process water, and the other to increased cooling and circulation; both of these help to conserve our dwindling supplies.

It should be noted that an analysis of recent statistics shows that supplies provided by public water undertakings in large urban areas in England and Wales have risen by 42% in the period 1938-56, while industry and agriculture both require more.

Reference has already been made to the introduction in 1920 of the heating value standard for gas, but in those days, in the minds of many, it was only the 'declared value' that mattered. Lately there has been an increasing realisation that gases of the same calorific value but of different composition may give very different effciencies of utilisation and so we now have to aim at the 'constant therm' and realise that factors other than calorific value are important, notably specific gravity and flame speed. Much research in various countries, has been devoted in recent years to what are called the 'combustion characteristics' of gas, but many people had the idea in mind earlier. In 1923 I was awarded the first prize at the National Gas Exhibition for a short essay on the following:—Give a percentage volumetric analysis of the gas you consider most economical to produce and consume, together with your reasons for each point of view.'

As a matter of interest, and for purpose of comparison, I give a summary of the main points from the essay. The gas composition given was CO_2 4.0%, O_2 .8%; C_nH_m 2.0%; CO 14.0%; CH_4 21.2%; H_2 48.0%, N_2 10.0%. Cal. value circa 480 B.t.u. per cu.ft., and '. . . . the essential requirement is to supply the consumer with a gas of constant quality and of such composition as to yield the highest efficiency in average appliances. The gas indicated will have a high flame temperature, hydrogen which causes most trouble through "striking back" is not too high in quantity, while methane and carbon monoxide, which permit of high primary aeration of the flame and a wide range of adjustability, are in good proportion. Incombustibles, which reduce the adjustability of the gas-air mixture and cause the flame to become very sensitive to pressure changes, are also within reasonable limits. . . .'

So much for 36 years ago; it was useful even if a long way from the details given by Gilbert and Prigg (I.G.E. 1956, Communication GC 35) on predicting the combustion characteristics of town gas. Their work was based on the methods of Delbourg (France) and Weaver (U.S.A.), and, following their procedure it is possible now from the analysis of a gas to predict its behaviour with reasonable accuracy.

Some happenings during the early days of C.W.G. were brought to mind by the paper of Gooderham and Mills (I.G.E. Research Communication GC4, 1952) on 'Some Effects of Traces of Iron Carbonyl in Gas.' This minor constituent of gas is responsible for red stains on the radiants and back blocks of gas fires. In 1891 Roscoe and Scudder showed that iron pentacarbonyl was present in water gas and was probably responsible for producing iron oxide in gas mantles. I remember several cases of compressed gas in cylinders being used for incandescent burners in marquees and after a short time the mantles were so coated with iron oxide as to emit a negligible amount of light.

It is not logical to consider the possible future of the industry without considering the education of those who will be responsible for running it. Just over a 100 years ago the first technical schools were opened in Britain; they had grown out of the mechanics' institutes. Perhaps one of the main contributions to general education in this country was the Great Exhibition of 1851, in which Prince Albert played such an important part. It indicated imminent competition from the Continent and brought the Science and Art Department at South Kensington into being in 1852, but it was nearly 40 years after the exhibition before the Technical Institution Act of 1889 was passed. The financial provision was meagre, but the situation was saved by "whisky money.' The Local Government Act was passed in 1888 empowering county councils to close redundant inns, in an endeavour to reduce the drunkenness then rife.

Curious Reflection

There was opposition from all sides, but in the Budget of 1890 6d. a gal. was added to spirit prices and the resulting revenue, together with a third of the duty on beer, was set aside to compensate licence holders. Again there was opposition and Parliament then agreed that the fund should be used by the county councils for technical education! It is a curious reflection on our attitude to education that we seem to take it so seriously in times of war. Thus 1918 saw the Fisher Act and 1944 the Butler Act.

Turning specifically to the gas industry, it is to be

noted that in the year 1923 the Education Scheme of the Institution was inaugurated. Passing over all the intermediate developments we should note the latest advance, the new Technological Award. Recognition of courses leading to the Diploma in Technology is not to be given lightly because the standard of the award will be equivalent to an honours degree of a British University. All this will mean that for a specialised subject such as gas engineering, the teaching staff will have to come from the industry, although it is difficult to see where they will be found.

What of the future of the industry? The general outline, at any rate of the immediate future, is already visible. I suggest we should consider two main aspects, the human and the technical. Taking the technical one first, it may be noted that, in general terms, since vesting date costs have risen by £150 mill. a year while revenue has increased by only £135 mill., and the difference of £15 mill. has been absorbed within the industry by integration and by increased efficiency. Operating essentially traditional processes, the overall efficiency has been raised from about 71% to 78%, but of course improvements of this sort are coming to an end, hence the vigorous activity in many other directions.

At the risk of over-simplification, always a dangerous procedure, I would say, ignoring subsidiary purification processes, that there are three main lines of change in gasmaking procedure to be envisaged. The first is to modify procedures in traditional carbonising plant, such as C.V.R.'s and I.V.C.'s, and in C.W.G. plants, which plants have considerable useful working life still remaining, so as to produce a portion of the gas from various oil feedstocks.

Complete Gasification

In view of the fact that, in future, the industry will have to use for its indigenous raw material small low-rank, non-caking coal, probably containing considerable inert material, there will be large complete gasification plants, having slagging producers, and operating at pressure with steam and oxygen. They will be sited preferably near the source of coal supply, and will be capable of applying the hydrogenation procedure to both coal and oil. Such plants will produce gas, low in carbon monoxide and sulphur, which will be fed into the grid or distribution system at pressures of the order of 400 lb. per sq. in. That is the second line of change, thirdly, there will be plants situated near suitable refineries or ports, capable of gasifying or reforming a variety of feedstocks, from heavy oil to imported liquid natural gas. They will thus be able to modify the carbon/hydrogen ratio of the feedstock so as to produce a gas interchangeable with that made by conventional methods, although I foresee a swing to higher calorific values.

In the minds of many people these developments will be viewed against the background of nuclear energy, but I see no cause for alarm because the two energy savers are really complementary. Let us examine a few of the possibilities. We hope that among the effects of nuclear energy development will be the release of quantities of cheap, low-grade coal for complete gasification, and of oil as a raw material for chemical industry, while eventually it may be possible to employ direct electrical heating, and also to produce hydrogen by electrolysis. It is also reasonable to envisage the use of such energy to upgrade carbon and so simulate growing plants which use solar energy to convert carbon dioxide into carbohydrates, proteins and fats.

Someone wrote recently, 'King Coal will rule for another century at least, split we the atom never so merrily.' There is much common sense in that because by no stretch of imagination can we afford to cut adrift from coal, our only indigenous source of combined carbon. However, we must alter our approach to its use. Whether we use coal or oil products we shall have to invoke a series of chemical reactions, many of which are highly pressure dependent, and most of which are capable of being catalysed, hence the tireless search for better and improved catalysts. Here again the nuclear energy projects may prove to be complementary because recently the effects of radiation on catalysts have been studied, and one of the most striking examples of improved catalytic activity is the effect found by Clarke and Gibson on an iron catalyst used in the Fischer-Tropsch synthesis, where the rate of conversion was increased by about 50%. From the initial power programme, which envisages the annual production, by 1965, of some 6,000 MW of electricity from nuclear power, the quantity of radio-activity obtained will be of the order of 3,000 mill. curies. By comparison the total world supply of radium gives approximately 1,000 curies, so there will be plenty of energy available for application to chemical processes which could be improved economically by radiation.

Turning to the human aspect of our look forward, it would appear, in retrospect, that everything was simpler and on a smaller scale 50 years ago, but that view may be coloured by alterations in my own outlook. Changes over the years have taken place, but they have been neither as rapid nor as far-reaching as they are today. People did not have to concern themselves with the many new governmental regulations we now have, nor with steering the right course between adequate control and decentralisation. The earlier gas engineer or manager, because there was a lot of them, was inclined to be a rugged individualist, but that may have been due, at least in part, to the conditions which prevailed, and to the environment in which he worked. The result was, in some cases, a ruthlessness which more recent developments have tended to mollify.

Business Maturity

Anyway, it is still true that the problems solved yesterday give rise to situations that create the problems of tomorrow, and what do we find? Among other things we note increasing signs of a mutual understanding between those engaged in technical matters, such as production, research and process development, and those more immediately concerned with business and finance. This indicates what we may call business maturity, and it has led, in its turn, to increasing attention being devoted to the human situation. In 1957, for example, the film 'Introducing Work Study' won the first prize in the Industrial Productivity Section at the Harrogate Festival of Films in the Service of Industry. Since then there have been films on education and training, health and safety, and human relations and welfare.

All this is excellent, but in our enthusiasm to pursue

this course we must also see that relative values are maintained and that human energy and time are not used unnecessarily. Various groups and associations now sponsor so many conferences, symposia, panel discussions and management courses that one begins to wonder how we shall go about trying to allocate our time. You will remember that the so-called Parkinson's Law states, 'Work expands so as to fill the time available,' and I suppose this is the origin of the cliché, 'when you want a job done, go to a busy man, the others haven't time.' One often hears the allegation that industry does not adopt inventions and improvements fast enough or willingly enough. We must remember that the industrialist and the scientist may very easily get so absorbed in the tactical trees that they fail to see the strategical wood!

We tend to get into a rut on controversial topics and to go on arguing about the merits or demerits of issues long after they have ceased to be live ones. So I would plead for clear and incisive thinking, because so frequently the issue is simply one of deciding which method costs least for a given level of efficiency. In the ultimate, our processes and methods, however attractive, will be of little value unless we can sell a service which is better and cheaper than that of our competitors.

We must also see that we are sought after more than in the past, because the gas industry has never been particularly attractive to the big financier, although this may have been partly due to many of the former companies being largely locally owned. The dividends paid were always modest and were controlled by Parliament or by private act, and I read recently that the average holding throughout the industry was well below £500 at vesting date.

The attitude we should adopt now is never to forget the importance of the gas industry to the nation, and thus to the individual. It is a great industry and has a capital of close on £400 mill. and is thus much larger than I.C.I., Unilever or any of the aircraft industries. If we strive to use our resources of capital and raw materials as effectively and flexibly as possible, we shall certainly obtain a fair proportion of the nation's estimated increase in energy requirements of 2% per annum over the next two or three decades.

GAS ON THE CONTINENT

High-Pressure Gasholders

IN 1957, the new German Code DIN 3396 for the design and construction of 'High-Pressure Gasholders Above Ground' was published. The following points are not mentioned in the Code, but they are of vital interest to the prospective and actual operator of such gasholders. If a spherical gasholder is chosen, less steel is required than for a cylindrical shape, because the latter requires twice the wall thickness for the same diameter and pressure. Nevertheless, cylindrical gasholders are preferred for small capacities, because they can be welded and pressure-tested at the works instead of assembled and X-ray tested on site. If complaints are raised against a scheme by residents, it should be emphasised that spherical gasholders introduce not the slightest risk, because no explosive gas mixtures can form inside. There is no gas leakage, since there are no moving parts, and they can be camouflaged behind trees where required.

Gasholders must, however, be located at a safe distance from roads and railway lines, where accidents may cause mechanical damage, or from works where fires may break out. The specification should lay down a steel quality with a high yield strength. Newly developed fine-grained steels with a yield strength of 22 tons per sq. in. possess weldability and low notch sensitivity. Contrary to the usual safety factor of 1.5 for pressure vessels, Code 3396 prescribes a safety factor of 1.8, to absorb additional stresses induced by support reactions and to safeguard against possible stress corrosion.

Stresses of 13 tons per sq. in. have, under adverse conditions, caused stress corrosion, although this has not yet been observed in high-pressure gasholders. At present, stressed samples of the steel used for the shell are left inside for observation over a number of years. If negative, the safety factor may be reduced to 1.6 later. To make provision for this contingency, it is recommended to specify an acceptance test pressure of 1.3 times the working pressure instead of 1.1 times.

To take a spherical gasholder into service, a gradual displacement of air directly by gas is recommended as the most economical way. At the worst, 18% of the total volume may consist of an explosive gas/air mixture which cannot possibly raise the pressure above safe limits. Rapid rates of discharge may lower the gas and wall temperature and this may adversely affect the strength of ordinary constructional steels (but not the fine-grained steel mentioned above).

H. Geilenkeuser. Das Gas-Und Wasserfach. Vol 99. No. 43. October 24, 1958. p. 1093.

Flow Measurement

A NEW book by Dr. W. F. Coxon, 'Flow Measurement and Control,' Coxon-Heywood Ltd., 55s., is written to provide information on this subject for the young chemical engineer. It forms one of a series 'Physical Processes in the Chemical Industry' under the general editorship of Professor J. C. Robb and Dr. Coxon. To a large extent the theory of the subject has been avoided and the problems of flow measurement are discussed in terms of its practical importance. Reference is made to the basic considerations particularly of flow measurement by use of differential pressure and an explanation is given of the various terms used by the flow engineer. Descriptions of details of the various types of fluid meter are provided and reference made to the practical formulae used in British Standard 1042: 1943. Various types of primary elements such as orifice plates, venturi tubes, etc., are covered.

The remainder of the book is largely of a practical nature, considerable space being given to the location of pressure difference devices and typical instruments used such as mechanical and electrical flow meters and automatic regulators of the pneumatic, hydraulic and electronic type.